Conceptual Design of the Long-term Ecological Monitoring Program for Denali National Park and Preserve

by

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May 8, 2000

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Preface

Denali National Park and Preserve was set aside in the early part of the 20th century to protect a living landscape, where visitors could see free-roaming wildlife against a spectacular backdrop of snow-capped mountains. It is a large park—2.4 million hectares (6 million acres). Except for a single road, the park is unfragmented and largely free from boundary encroachments. To protect and preserve this landscape, the National Park Service (NPS) must keep track of—monitor—the landscape and the wildlife populations that live in it. Such monitoring will alert park managers to problems affecting the land and wildlife, in order to correct them. Monitoring also will build understanding of the landscape. This understanding is crucial to the park's ability to be pro-active in preventing problems. Because the NPS's mission is to protect and preserve, prevention or avoidance of problems is critical.

Over the years, Denali has supported and been the site of many studies, some repeated often enough to constitute informal monitoring. Park managers have long recognized, however, the value of a formal system for monitoring park resources. Development of a monitoring program became a possibility in 1992 when the park began to receive funding from a national-level program within the NPS for that purpose. At the same time, the National Biological Service (predecessor to the U.S. Geological Survey, Biological Resources Division) began to receive funding to work cooperatively with Denali to develop the monitoring program by conducting research for the program's design. Thus began a joint effort of the NPS and the USGS to develop the Denali Long-term Ecological Monitoring (LTEM) program that continues to this day.

In 1995, a national panel visited the park to review the monitoring program. The panel recommended that the park develop a stronger conceptual basis for the monitoring program documented in a written conceptual plan (Frederick 1996). To this end, the park held two workshops in 1996. These workshops, which involved more than 40 subject matter experts and NPS personnel, helped develop program objectives. The workshops also provided a forum for discussions on how to improve links between the monitoring program and resource preservation questions. Results of the workshops were incorporated into a draft *Conceptual Design* (Denali National Park and Preserve 1997a). This new *Conceptual Design* builds on the 1997 document and incorporates lessons learned from the monitoring activities themselves, ongoing since 1992. Perspectives on monitoring from recent literature also have been added.

This document will guide the Denali LTEM program and addresses concerns identified by the 1995 review. Most importantly, this document clarifies the type of monitoring that will occur at Denali and sets a single goal of helping park managers protect park resources by providing the ecological context for resource preservation decisions. Having a single goal provides the necessary basis for prioritizing monitoring work.

This goal will be met through a *management focus* objective, targeting early warning of adverse changes, and through an *ecological focus* objective, targeted at ecosystem understanding. We describe a conceptual model of the Denali Ecosystem, which forms the basis for the four building blocks—termed components—of the program: *physical environment*, *aquatic systems*, *vegetation*, and *wildlife*. Monitoring in each component will be led by one or more Park Leads, who will integrate data from monitoring with data from inventory, research, and other sources. We also consider potential sources of adverse effects to key values of the park, concluding that the most significant sources stem from concerns that lead to increased access or result from increased access, and from global industrialization. We discuss strategies for how the components of the monitoring program will develop information to help the park prevent or mitigate problems stemming from these sources. We also provide guidance on general features such as program management, how information will be reported, and protocol documents.

We believe the design presented here answers questions raised in 1995. More importantly, we believe the design sets the stage for the long-term ecological monitoring program to fulfill its critical role in preservation of the Denali Ecosystem.

Introduction

The ability to detect and document resource changes, and to understand the forces driving those changes, are fundamental to accomplishing the National Park Service (NPS) mission of conserving parks unimpaired (National Park Service 1992). In 1991, the NPS selected several parks representing different biogeographic provinces, to serve as prototypes for development of Long-term Ecological Monitoring (LTEM) programs. Denali National Park and Preserve (Denali) was one of these prototypes, selected to develop and test methods for monitoring in subarctic parks.

This document is the blueprint for the Denali LTEM program. We lay out the thinking that drives the design, and describe the design itself. We also address features of the program common to all components. These features make it a program rather than an assortment of projects. This program is long-term, intended to monitor the ecosystem of Denali over decades if not centuries, making a written statement of vision and purpose critical. This *Conceptual Design* document will record and help communicate the purposes and structure of the program as program management changes hands through time.

This design integrates what has been learned at Denali since 1991 with current literature on inventory, monitoring and long-term studies. The design described here differs significantly from the original design, which took a watershed approach. In the original design, monitoring effort eventually was to have been allocated among five major watersheds spread throughout the park. For logistical and financial reasons, monitoring focused on a single watershed—the Rock Creek drainage—near the park entrance (Thorsteinson and Taylor 1997). Whether this intensive monitoring effort at a single site would provide data to address the most important resource preservation concerns of a 2.4 million hectare (6 million acre) park became a significant question—leading to a re-evaluation of the monitoring program. The conceptual design presented here is the result of that re-evaluation and reflects many valuable lessons learned from the original program.

What is Denali All About?

Denali National Park and Preserve encompasses 2.4 million hectares (6 million acres) of largely mountainous terrain in the Interior region of Alaska (Figure 1). Denali includes Mount McKinley, at 6,194 meters (20,320 feet), the tallest mountain in North America. The Mount McKinley massif is highly glaciated, and 17 percent of the park is covered with glaciers. Surrounding lands include alpine tundra and taiga (boreal forest), and they support a diversity of wildlife species, including wolves (*Canis lupus*), Dall sheep (*Ovis dalli*), moose (*Alces alces*), caribou (*Rangifer tarandus*), grizzly bears (*Ursus arctos*), furbearers, fish, birds and invertebrates. The park was established in 1917 to set aside Mount McKinley and to protect caribou and sheep populations from market hunting. The original vision of the park was as a living landscape and a “park-refuge” (Sheldon 1930).

Over time, our sense of the significance of Denali National Park and Preserve relative to similar resources elsewhere in the United States and the world has evolved. The key values of Denali (Table 1) capture the essence of Denali’s importance to our nation’s natural and cultural heritage.

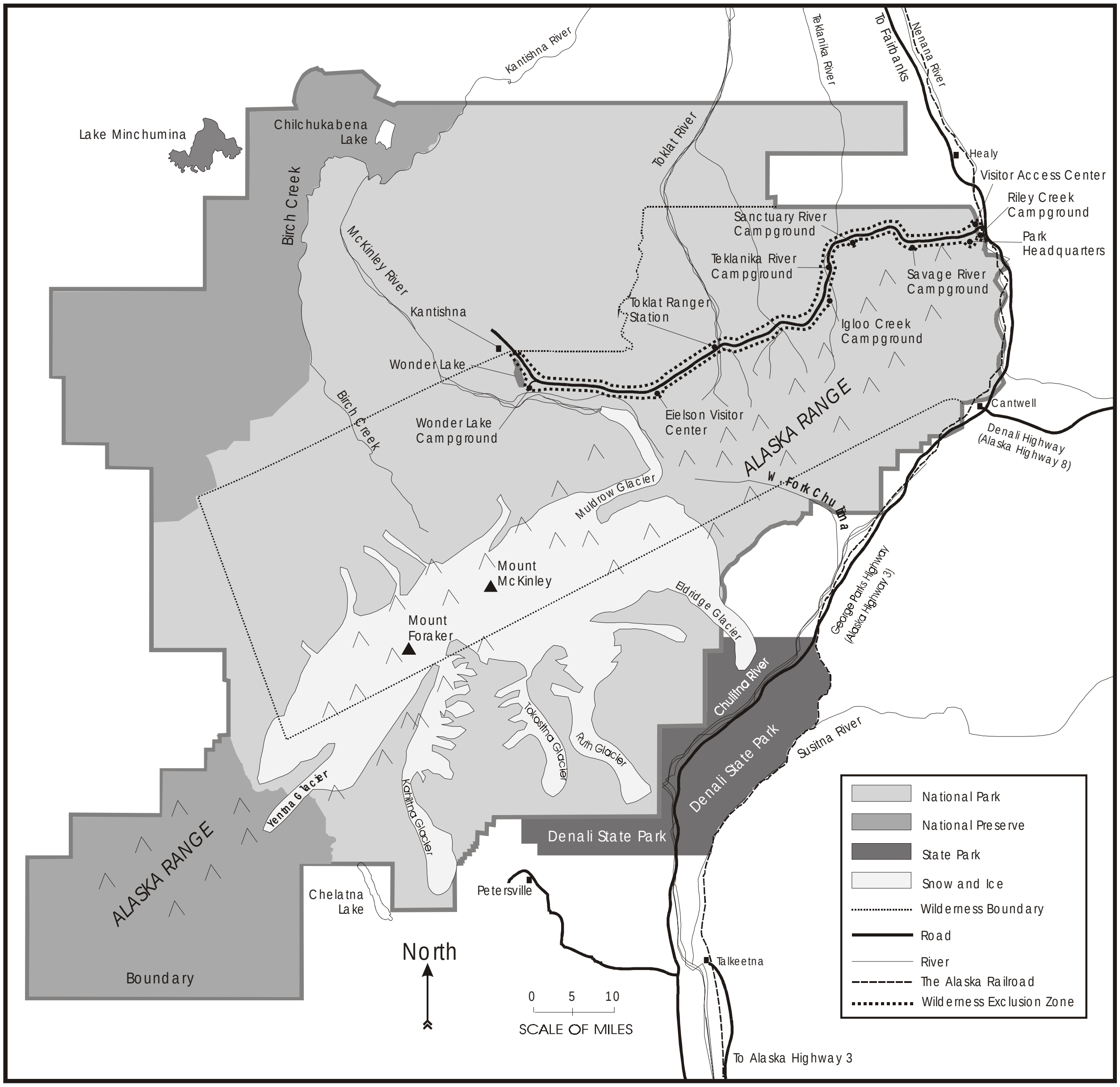
Because of its vast beauty and viewable wildlife populations, Denali is currently one of the prime visitor destinations in Alaska, receiving more than 300,000 visitors per year, mainly during the summer. The main access into the park is a 144-kilometer (90-mile) gravel road, originally built to support park visitation and mining development in the Kantishna area (Figure 1). The NPS instituted a bus system in 1972, and restricts the number of vehicles using the park road to protect the area from too much traffic. Major legislation in 1980 [Alaska National Interest Lands Conservation Act (ANILCA)] greatly expanded Denali [it went from 800,000 hectares (2 million acres) to 2.4 million hectares (6 million acres)] and created three management designation: “old” park, “new” park, and preserve (Figure 1). These designations determine the management goal and thereby the activities allowed within each administrative unit. In recognition of the unique character and development of Alaska, subsistence ways of life are provided for in the new park and preserve, and sport hunting is provided for in the preserve.

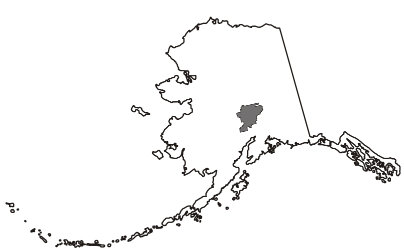
Although Denali is one of the most pristine units within the NPS system, Denali has important resource preservation concerns. The central, overriding concern for Denali has been, and probably always will be, how to protect the park-refuge interior of the park, and its wildlife populations, given increasing demands for public access and increasing development pressures both within the park and along the borders of the park (Brown 1993, Denali National Park and Preserve 1998).

Table 1: Key values of Denali National Park and Preserve

Value	Definition
International Significance	Proclaimed an International Biosphere Reserve by the United Nations for its potential for subarctic ecosystems research. Visited by people from many countries, and by managers of other protected areas looking for examples of successful visitor management and resource protection.
Ecosystem	Intact and naturally regulated subarctic ecosystem that is still essentially unfragmented by access routes or boundary effects.
Wildlife	Outstanding opportunities to view wildlife as a part of a naturally functioning ecosystem.
Plant Life	Outstanding opportunities to view subarctic plant communities.
Wilderness	Large, intact wilderness that still offers premier wilderness recreational opportunities, including the opportunity to climb one of the world's premier mountaineering destinations and to experience a natural soundscape.
Geology	A complex and diverse geology of international interest, including the Central Alaska Terrane Assemblage and the Mount McKinley massif.
Glaciers	A range of glacier types that characterize the subarctic and currently cover 17% of the park's surface area.
Air Quality and Scenic Resources	Clean and protected air quality preserving internationally significant vistas.
Cultural Resources	Many historic and archeological sites, associated with Athabascan Indian groups, early explorers, mining history, and early days of the park.
Access and Tourism	A unique bus trip that transports visitors through a narrow corridor into the wilderness, with prime wildlife viewing areas.
Subsistence Uses	Continuation of customary and traditional uses by rural Alaska residents of wild, renewable resources for personal or family consumption or use within the 1980 park additions and the preserve.
Research	A combination of management designations (old park, new park, and preserve) with a range of mandates that provides internationally recognized opportunities for long-term studies of the relationships between human activities and subarctic ecosystems.

Figure 1: Map and Location - Denali National Park and Preserve, Alaska





Location in Alaska

The mission of Denali National Park and Preserve is to:

- ensure the protection of wildlife, natural and cultural resources, and aesthetic and wilderness values along with the use and enjoyment of the park by present and future generations;
- ensure that visitors understand and appreciate the significance of natural systems;
- sustain subsistence lifestyles; and,
- provide a setting conducive to scientific investigation (Denali National Park and Preserve 1997b).

Introducing the Goal and Objectives of the Denali LTEM Program

The Denali LTEM program will support the mission of the park by the development of broadly based, scientifically sound information on the current status and trends of the physical and biological resources of the park's ecosystem.

We have set a single goal for the monitoring program: to help park management protect the resources of Denali by providing the ecological context for resource preservation decisions. We have set two objectives to meet this goal:

> *Management focus objective:* To provide timely information to decision makers to determine if the ecological status and trends require a change in management.
>
> *Ecological focus objective*: To improve understanding of the Denali Ecosystem.

Guide to This Document

The Conceptual Design is divided into three parts. In Part I, we lay the groundwork for the design. In Part II, we present the design itself. In Part III, we describe general programmatic features.

In Part I, we provide context for the program's design:

- **How We View Long-term Ecological Monitoring—**We define distinctions among inventory, monitoring, and research, and among three types of programs that involve repeated measurements. Differences in expectations about the monitoring program will reduce confidence and erode program success. We thus define our view of long-term ecological monitoring and the vital role the program will play in protecting and preserving Denali's ecology.

- **Our Development Process—**We describe the process we are using in developing the monitoring program. This process combines recommended processes from other programs into distinct design, testing and implementation stages. Our process also includes checkpoints to ensure that program development stays focused on the goal and within budgetary limits.
- **Role of Modeling—**Modeling will play an important role in the design and implementation of the monitoring program. Conceptual models of important relationships and processes in the Denali Ecosystem will form the foundation of monitoring. Modeling will be used to refine our selection of monitoring attributes. Models become critical during implementation by defining expected results and providing a basis for comparison. Models also will provide a structure to incorporate data generated by monitoring.
- **The Denali Ecosystem—**Attributes selected for monitoring should reflect current understanding of ecological relationships and the most important driving forces in the ecosystem. We thus provide a synthesis of our current knowledge and introduce the models we have built. These descriptive models—for general patterns of climate, aquatic systems, vegetation and trophic relationships among plants and animals (food web)—integrate our knowledge about the most important processes and relationships in the Denali Ecosystem.
- **Resource Preservation Concerns**—This chapter defines the management context of the monitoring program. We consider the key values of Denali, review past and present resource protection and preservation concerns, and identify the most important future concerns. We consider relationships among the issues, leading to a ranking of their relative importance.

In Part II, we lay out the design of the Denali LTEM program.

- **The Goal and Two Objectives of the Denali LTEM Program**—We return to a consideration of the goal and objectives for the program. We describe the logical links between the mission of the NPS and Denali National Park and Preserve and the goal and objectives of the monitoring program.

- **Organizing Monitoring Effort**—Here, we define the building blocks, or components, of the monitoring program. These are *physical environment, aquatic systems, vegetation* and *wildlife*. The selection of these units of effort for our monitoring work is based on our conceptual ecosystem model.
- **Linking Monitoring Components to Resource Preservation Concerns**—Here, we discuss strategies for linking monitoring components to the highest priority resource preservation concerns. This framework ties together the ecosystem model and preservation concerns to ensure that the monitoring program will be relevant to future management decisions.
- **Transition to the New Conceptual Design**— The design of the Denali LTEM program will not be finished until the specific designs for each monitoring component have been revised in light of the goal and objectives established here. Using ongoing work in the *Vegetation* component as an example, we discuss transition to the new conceptual design.

In Part III, we address those aspects of the program common to all the components and that make it a program's rather than an assortment of projects. These aspects of the program include:

- **Program Management**—In this section, we describe how the Denali LTEM program will operate as integral part of park management. Two of the major elements for any program involve the formation of a core staff and maintaining a long-term commitment and funding base. We describe the specific role of the Park Leads, financial management, and administrative reporting.
- **Information Management and Transfer**—Here, we discuss the methods that will be employed to maximize the use and value of LTEM data. We will begin with a discussion on quality assurance and quality control, then describe our current strategy for data management, and finish with a brief overview of how monitoring results will be reported. We also address the importance and role of collaboration.
- **Key Features of Protocol Documents**—A protocol–a written study plan–will be required for each component of the monitoring program. The protocols will consist of a narrative that describes what will be done and why, and Standard Operating Procedures (SOPs). Use of well-defined protocols will help prevent measurement errors and ensure that the quality of the data is known.

Part 1: Laying the Groundwork

Chapter 1
How We View Long-term Ecological Monitoring

Critical distinctions exist among inventory, monitoring, and research and among the various types of monitoring programs. Not recognizing these distinctions can result in a mismatch between expectations and outcomes. A monitoring program's success depends upon all stakeholders having realistic expectations about what the program is supposed to deliver. Making sure that these expectations are realistic at the outset is especially important, as a program may take 10-15 years to produce data that make the program's merit clear (McDonald et al. 1998). Different types of monitoring programs also dictate different statistical approaches. Thus, the purpose of monitoring must be clear from the beginning or the data may be inappropriate for their intended use (Overton and Stehman 1995). We begin by reviewing the differences among inventory, monitoring and research and by defining long-term ecological monitoring, and how it differs from other forms of monitoring.

Differences Among Inventory, Monitoring and Research

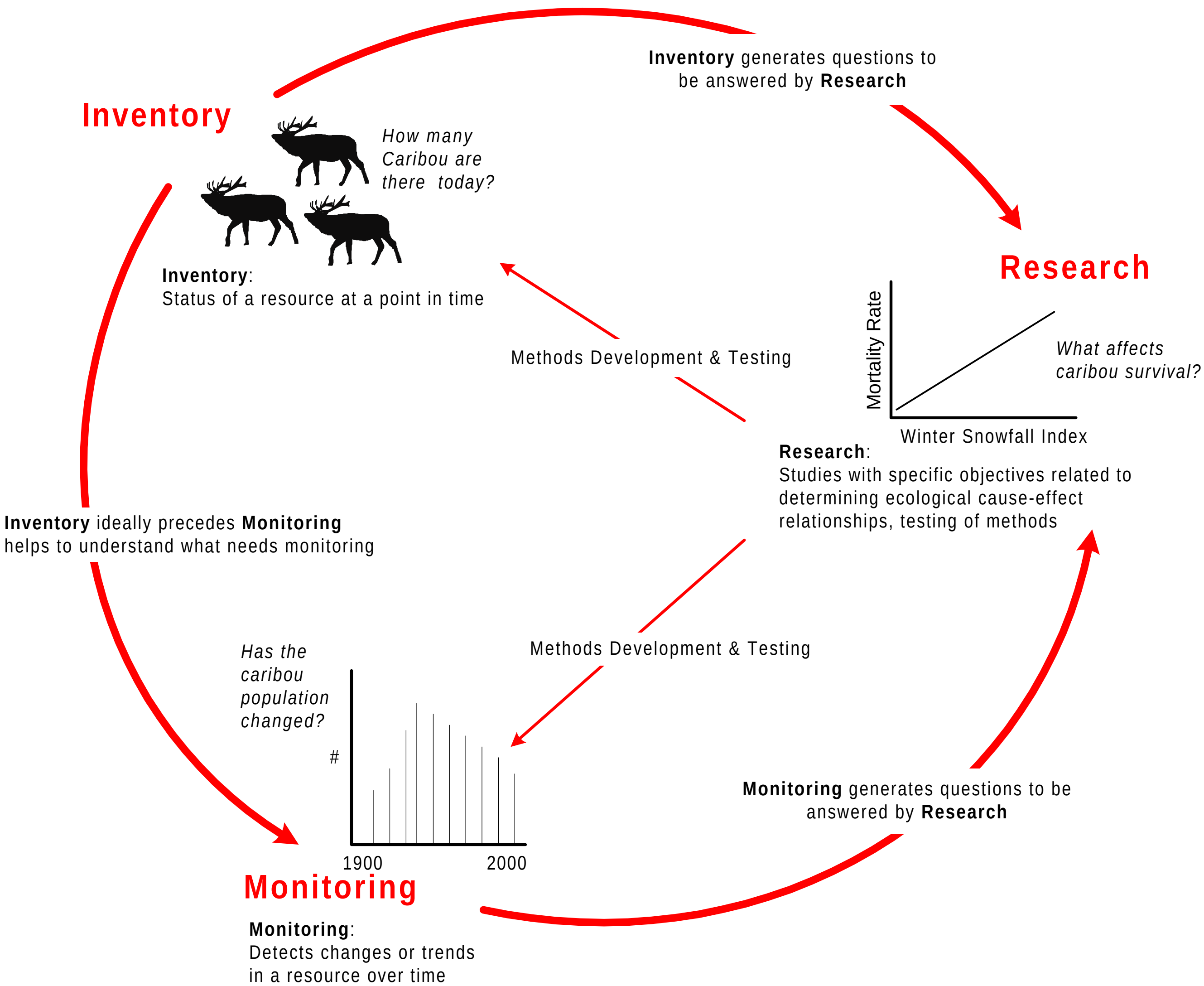
We define "inventory" as *an assessment of the status of a resource <u>at a point in time</u>*. Inventories typically describe the occurrence, distribution and/or abundance of a resource. Inventories are often used to determine the status of a resource that is rare, and thus inventories characteristically will employ a stratified design, where search or study effort is concentrated in areas considered most likely to detect the given resource. Inventories usually will require an intense effort aimed at getting a complete picture of the status of the resource. The inventory data will then be used to target follow-up research or monitoring.

The dictionary defines monitoring as "to watch" or "to keep track of" or "to check on" (Fuller 1999). Thus, monitoring differs from inventory by adding the dimension of time. We define "monitoring" as *repeated measurements <u>over time</u> for a purpose*. The general purpose of monitoring often is to detect changes or trends. Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring efforts will differ in terms of their spatial and temporal scales, depending upon their purposes. While repeating inventories is one way of approaching monitoring, this is rarely the most efficient method. Often monitoring will require a different approach. Based on a review of programs that involve repeated measurements, we have defined three types of monitoring programs, which we discuss in some detail in the following section.

Although any scientific effort, including inventory and monitoring activities, can be broadly defined as “research”, we will use a narrower definition here. In ecology, research projects generally are designed to determine the causes of observed ecological phenomena. Research will be set up in a hypothesis-testing mode to determine whether a given treatment is the cause of an observed effect. With respect to inventory and monitoring, research also is required to develop and test appropriate methods.

To protect and preserve the natural resources of Denali, park managers will need to include all three types of activity—inventory, monitoring and research—in its resources program. The three activities are, in fact, related, and in some respects, co-dependent (Figure 2). Ideally, inventory precedes monitoring to provide a basis to design monitoring efforts. Monitoring is used to detect changes in resources that inventory reveals as important. Research is used to develop inventory and monitoring methods and to investigate questions that arise from inventory and monitoring data.

Figure 2: Relationship Among Inventory, Monitoring and Research



Differences Among Monitoring Programs

Depending on its purpose, monitoring can take different forms. Based on review of existing programs that involve repeated measurements in a variety of natural resource-related agencies, we suggest that monitoring programs can be classified into three general types: (1) *Long-term Studies*, (2) *Adaptive Management Monitoring*, and (3) *Long-term Ecological Monitoring* (Figure 3). Distinctions among these types of programs can be confusing because all involve data collection over long periods of time. However, we have observed that monitoring programs can be aligned along a gradient from monitoring with a strict research focus to monitoring with a strict management focus, with some programs intermediate. We consider this monitoring program gradient as a prelude to explaining the monitoring role the Denali LTEM program will play.

Long-term Studies

Long-term studies in ecology are required to elucidate such phenomena as (1) slow processes, (2) rare or episodic events, (3) processes with high variability, and (4) subtle and/or complex processes (Likens 1989). The earliest *long-term studies* involved individual researchers able to acquire funding to continue work over their lifetimes, and the transfer of the work to a student or colleague when they retired. *Long-term studies* are typically site-specific (i.e., localized), and involve detailed investigations of ecological processes.

Long-term studies involve monitoring—repeated measurements over time for a purpose—to understand ecological phenomena that can only be studied over decades or centuries. An important lesson from *long-term studies* as a class of scientific inquiry is that conclusions from a typical research project (2-5 years) can be proved wrong when a longer series of data is examined. Serendipity can also play an important role (Strayer et al.1986). A serendipitous finding is an important finding that was not planned for in the original design of the study. Although serendipitous findings are relatively rare, they may be of great importance. For example, the discovery of acid precipitation through long-term studies at the Hubbard Brook watershed in New Hampshire was an important serendipitous finding. The detection of pre-atomic age levels of radioactivity in soil samples taken at Rothamsted

Figure 3: Comparison of Three Types of Programs that Involve Repeated Measurements

Adaptive Management Monitoring

Description:

- Integral part of a management program
- Cause-effect is known, specific change to be detected is known.
- Thresholds, management actions, pre-determined.

Examples:

- Salmon escapement monitoring
- Denali bear-human interaction monitoring
- Effectiveness monitoring program for the Northwest Forest Plan
- North American Waterfowl Management Plan

Long-term Ecological Monitoring

Description:

- Link to management is there but generalized, not as specific as in adaptive management monitoring
- May attempt to detect changes over broad spatial scales, for many resources/indicators
- Broad-brush approach may allow detection of changes that could not be foreseen.

Examples:

- National bird programs (Breeding Bird Survey, Christmas Bird Count)
- U.S. Forest Service, Forest Health Monitoring Program
- General Ecological Monitoring Program at Channel Islands National Park

Long-term Studies (sensu Likens 1989)

Description:

- Long time scale required to understand slow processes, rare events, processes with high variability, and subtle/complex processes.
- Purpose is to understand ecological relationships, cause-effect relationships.
- Spatial scale of work is often limited.

Examples:

- National Science Foundation's Long-term Ecological Research (LTER) program, including: Hubbard Brook (New Hampshire), H.J. Andrews Experimental Forest (Oregon), Bonanza Creek (Alaska)
- Rothamstead Park Grass (Great Britian)

Park Grass (an agricultural experiment station established in England in the mid-1800s and generally acknowledged as the longest *long-term study* of record) is another example.

The importance of *long-term studies* to our overall understanding of ecological phenomena has been recognized by the National Science Foundation in their funding of the Long-term Ecological Research (LTER) network (Callahan 1984). The LTER network incorporates some of the oldest long-term study sites in the country (e.g., Hubbard Brook). The LTER program now has 21 sites, including two sites in Alaska—Bonanza Creek Experimental Forest/Poker-Caribou Creek Watershed near Fairbanks and Toolik Lake in the Brooks Range. Studies at Bonanza Creek LTER focus on ecological processes in the taiga, and much of the work there is directly relevant to Denali.

Adaptive Management Monitoring

At the other end of the gradient from *long-term studies*, is what we call *adaptive management monitoring*. This type of monitoring has also been called implementation monitoring (Elzinga et al. 1998). In this type, monitoring is an integral, in fact, inseparable, part of a management program. Research has established a cause-effect relationship, allowing managers to choose an appropriate indicator and a pre-determined threshold for management action.

Examples of *adaptive management monitoring* include regulatory monitoring for pollutants (e.g., water and air quality monitoring), salmon escapement monitoring (harvest levels are set based on the number of fish making it to spawning grounds), and the annual monitoring of duck populations and harvest used to implement the North American Waterfowl Management Plan (Williams et al.1999).

Adaptive management monitoring is not inherently long term. However, this type of monitoring may be conducted over long time-periods because of high public values (i.e., maintenance of healthy air and water, sustained production of valuable resources such as salmon and waterfowl). Data sets generated by *adaptive management monitoring* may serve two purposes: (1) they trigger management actions in an immediate time frame, and (2) they generate data sets useful for continued improvement of our understanding of cause-effect relationships and patterns of change. However, data collected for one purpose may not be appropriately used for another purpose (Rose and Smith 1992).

An example of *adaptive management monitoring* at Denali is its program to minimize bear-human conflict (Schirokauer and Boyd 1999). This program includes visitor education, food-storage regulations, backcountry closures, and experimental aversive conditioning of bears that have obtained human food. An integral part of this management program is real-time tracking of bear-human incidents. The tracking of incidents triggers the immediate aversive conditioning of bears that have obtained human food. This tracking (done informally in the past, but formalized now in a Bear Management Information System) also has allowed an analysis of the success of the management strategies in reducing bear-human conflict.

The Effectiveness Monitoring Program for the Northwest Forest Plan is another example of *adaptive management monitoring* (Mulder et al. 1999). This program will determine if federal land managers are meeting the goals of the multi-agency Northwest Forest Plan, and provide early warning of changes that management action could correct. The program relies on identification of stressors, both natural and anthropogenic, and construction of conceptual models linking the effects of those stressors with changes in ecosystem structure and function. This stressor analysis is used to select indicators for monitoring, and thresholds for management action are established.

Long-term Ecological Monitoring

Some monitoring programs do not fit exactly into either the *long-term studies* or the *adaptive management monitoring* categories. Thus, we defined a category called *long-term ecological monitoring*. If *long-term studies* represent the research end of the monitoring spectrum and *adaptive management monitoring* represents the management end of the monitoring spectrum, *long-term ecological monitoring* represents a kind of middle ground between the foci of research and management.

Long-term ecological monitoring typically involves monitoring the population status of a wide variety of species or ecosystem attributes whose immediate relevance to management issues may not be clear or explicitly justified. This type of monitoring also may involve large spatial scales and may attempt to employ unbiased study designs to allow the monitoring program to make inferences about what is changing over the landscape. While links to specific management actions are often desired in *long-term ecological monitoring* programs, the links may be unclear, at least at the outset. The primary goal is to detect changes or trends, <u>including changes or trends that are unexpected</u>. This differs from *adaptive management monitoring* where the change you want to detect is known.

National landbird monitoring efforts including Christmas Bird Counts and Breeding Bird Surveys are examples of the large-scale, general monitoring that we call *long-term ecological monitoring.* These monitoring efforts have detected declines in populations of neotropical migrants such as the Blackpoll Warbler (*Dendroica striata*) and Olive-sided Flycatcher (*Contopus borealis*). Detection of these population declines, which were not foreseen or predicted when these monitoring efforts began several decades ago, has triggered additional studies into the causes of the declines. While the results of landbird monitoring are important to resource managers, the relationship between monitoring results and management actions was not initially apparent. Now that these programs have detected phenomena of management interest, the value of the data seems obvious and continuation of these programs seems secure.

The General Ecological Monitoring program at Channel Islands National Park (Davis 1997) offers another example of *long-term ecological monitoring*. The Channel Islands program, which began in 1981, includes population monitoring of various species and selected environmental parameters such as sea surface temperature. The population data have helped the park with issues such as removal of exotic species, restoration of overexploited abalone populations, and detection and mitigation of pollution. By providing reliable scientific information about the ecosystem to managers, the program reduced their uncertainty in decision-making. While one of the goals of the Channel Islands program is to identify potential agents of abnormal change, the program recognizes that establishing cause-effect relationships is beyond the scope of the program. The Channel Island program is an excellent example of the application of long-term monitoring in the national park context.

History of the Conceptual Design of the Denali LTEM Program

This overview of the three major types of monitoring programs provides a segue into the history of the conceptual design of the Denali LTEM program. In retrospect, it appears that the original program was set up like a long-term ecological research (LTER) site (or network of LTER sites) (Thorsteinson and Taylor 1997). The original program also seemed to focus on studying effects of a single, albeit important, issue: global warming.[1] After a few years, some of the limitations of this approach became apparent, as was highlighted by the 1995 national review panel (Frederick 1996). The most important limitations involved the lack of a clear relationship to resource preservation concerns and a mismatch between the spatial scale of the monitoring effort (watershed) and the spatial scale of interest to park managers (the landscape).

Perhaps in reaction to the apparent LTER-focus of the original program, the next phase of conceptual development favored an *adaptive management monitoring* approach, following, in general, the stressor-based approach to effectiveness monitoring for the Northwest Forest Plan (Mulder et al. 1999). Two planning workshops held in 1996 were organized around the stressor approach. The 1997 Conceptual Design document (predecessor to this document) captured the results of those workshops and laid out a design based on the stressor approach.

After closer examination, the stressor-based approach seems more appropriate for managed lands than for protected lands—a conclusion that the team designing a long-term monitoring program for Olympic National Park also reached (Woodward et al. 1999). The approach we now favor to monitor the ecology of Denali and that we describe in the remainder of this document, is

1. Global warming is still recognized as an important resource preservation concern for Denali. However, global warming is just one of several concerns that the Denali LTEM program addresses. (See Chapter 5 on *Resource Preservation Concerns*.)

most closely aligned with the approach we have labeled *long-term ecological monitoring*.

With this background in mind, we conclude that an effective resource protection and preservation program at Denali should, and does, include all three types of activity: inventory, monitoring and research. The overall program also should include, or provide for, the three types of monitoring that we have identified. *Adaptive management monitoring* will ensure that management actions have their intended effects. Denali also should provide a setting for *long-term studies*. Such studies can help elucidate the dynamic processes of Denali ecosystems. Finally, the resource preservation program needs to include *long-term ecological monitoring*. As a protected area, Denali needs to keep track of a wide variety of ecosystem attributes that can help alert us to changes in the environment and provide understanding of the ecosystem.

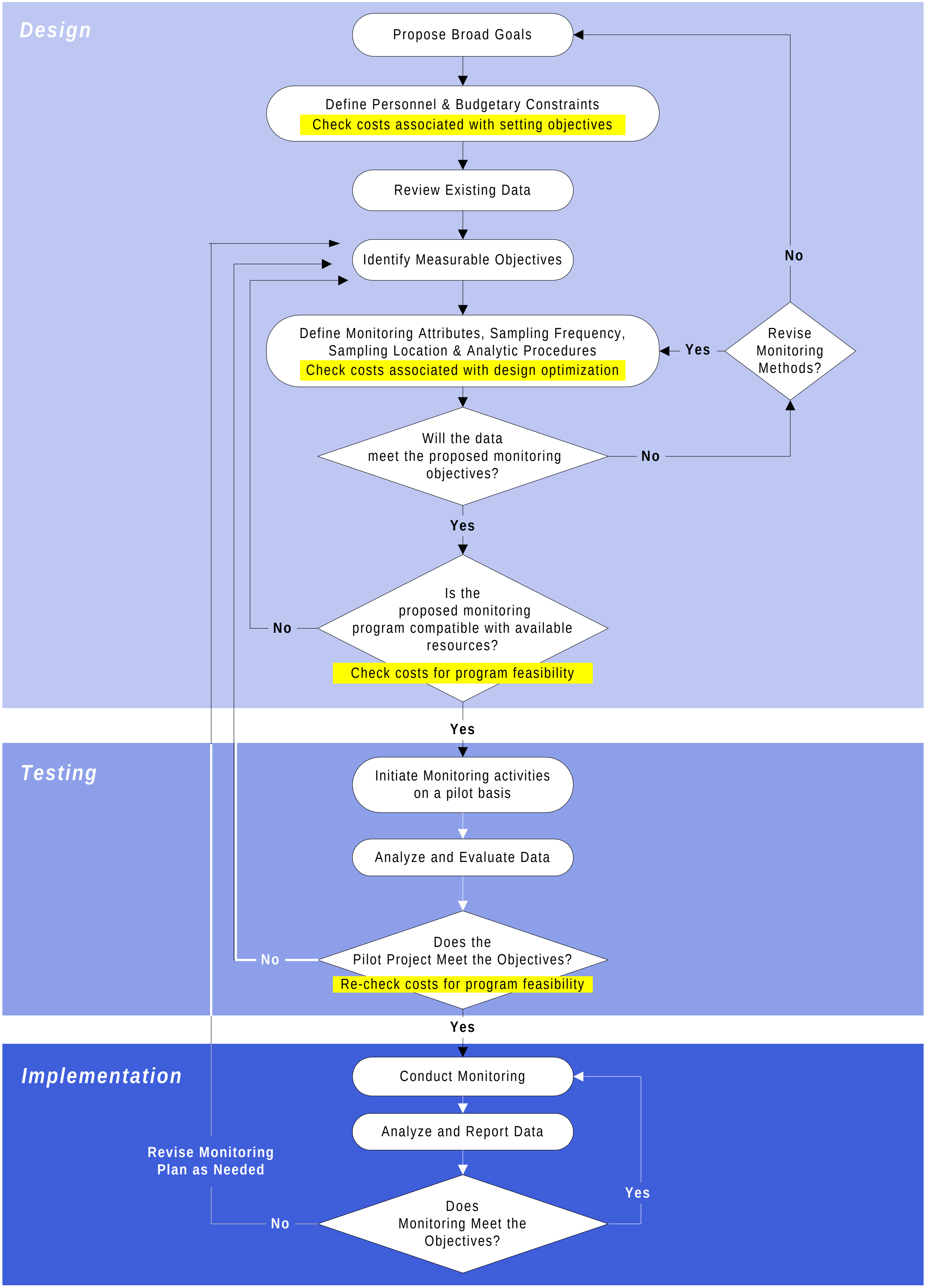
Chapter 2
Program Development Process

Several authors have suggested steps to follow in developing a monitoring program (Hinds 1984, Jones 1986, MacDonald et al. 1991, Davis 1993, Silsbee and Peterson 1993, Elzinga et al. 1998). Caughlan (2000) consolidated and integrated these steps into an idealized process (Figure 4) that we are using. The process includes four checkpoints to ensure there is a match between objectives and feasible and affordable methods. In addition, the process is dynamic; it does not end once the program is implemented. The data must be analyzed and reported continually to ensure that the program continues to meet the stated objectives. If the monitoring effort is not meeting its objectives, program managers will need to revisit and possibly change the objectives (leading to a change in what is monitored), or revise methods so that the original objectives can be met.

In overview, the development process includes the following major stages: design, testing, and implementation. Each of these major stages has many steps, and involves different players. For example, upper level managers set the broad goals of the program and determine the resources available for monitoring. The monitoring program manager and park staff responsible for each component of the program are responsible for setting measurable objectives and weaving the various data streams into a coherent whole. Statisticians and subject area experts help develop methods and sampling designs. External peer reviewers provide feedback to ensure that the program uses the most appropriate methods for the objectives.

In the development and implementation of the Denali LTEM program, the Program Manager oversees the program development process. The monitoring program involves several building blocks, or components (described in Chapter 7), and each component may be in a different stage of the development process at any time. However, the development process should eventually lead to the point where monitoring in each component has reached the implementation stage.

Figure 4: Monitoring Program Development Process



Chapter 3
Role of Modeling

Most, if not all, monitoring programs include a modeling step in the design stage. Modeling, in the sense described by Starfield (1997), forms an important part of the Denali LTEM program, not just in design, but also in implementation. The Starfield approach is pragmatic, with models used as problem-solving and communication tools. A pragmatic model is a purposeful representation that includes only those features of reality essential to the purpose of the model (Starfield et al. 1994). Models are constructed quickly (and inexpensively), mainly for what is learned from the process of building and regularly exercising them. The primary value of these types of models is gained from the process of building and using them; therefore, we are building the models ourselves, rather than by treating model building as a task for specialists.

Our reliance on modeling to focus our monitoring work requires that each protocol include a section that presents the model(s) specifically developed for that monitoring component. The model(s) also will address how the component is integrated with the overall program. The models serve at least two critical purposes—first in design (helping assure that we have selected the right attributes to monitor) and later, in implementation (by giving us something to check our data against to see if reality matches our expectations).

In the design stage, modeling exercises will help us understand where our effort can most effectively be deployed. Sensitivity analysis can be used to see if collecting data on attribute x makes a difference, or more or less of a difference than collecting data on attribute y. Models can help us focus on the “so what” question. For example, they can reveal where a lack of data is critical, and where a lack of data will not affect management choices. Modeling exercises at the outset, during the design stage, will solidify our confidence that we have selected the most appropriate attributes and sampling designs.

In implementation, once data collection begins, our models can suggest how the data for a given year should appear. The model thereby gives us something to check our data against to see if reality matches our expectations. If the data do not match our expectations, we revise the model to incorporate this new information. We might also reconsider whether the data being collected are appropriate, or whether different attributes need to be measured. If the data do match expectations based on the model, we gain confidence that our understanding of how the ecosystem operates is correct.

Small mammal monitoring in the Denali LTEM program provides an example of the application of modeling in a monitoring context. When small mammal monitoring began in 1992, our model of small mammal populations, based on literature from studies conducted elsewhere, would have been that their populations would likely be cyclic, with a 3-4 year periodicity. Based on monitoring at Denali thus far (8 years), populations of the red-backed vole (*Clethrionymous rutilus*), the most common small mammal species, have varied by an order of magnitude among years, with no evidence of a cycle (Rexstad and Debevec 1999a). Rather, their autumn population size appears to depend strongly on conditions in spring and early summer. If the voles born early in the summer experience favorable conditions, they survive to reproduce that year, thereby producing a bumper crop of voles. If these voles experience less favorable conditions, they may die (and obviously, they would not reproduce), and the autumn vole population would therefore be smaller. Based on monitoring thus far, our working model of vole population dynamics is different from the model we began with.

Chapter 4
The Denali Ecosystem

Having just expressed our intention that models play a central role in the Denali LTEM program, we now begin the process of creating a conceptual model of the Denali Ecosystem. Because monitoring programs must be matched to the ecosystem being monitored (Soballe 1997), building an initial ecosystem model is a crucial step. The conceptual ecosystem model is the vehicle used initially to describe current understanding of the ecosystem. The attributes selected for monitoring will reflect current understanding of the important characters and driving forces in the particular ecosystem. As monitoring progresses, the model becomes the vehicle used to integrate the monitoring data. Monitoring (or subsequent events that were not part of monitoring but were too obvious to ignore) may reveal that an important feature of the ecosystem has been overlooked or misunderstood (Soballe 1997). The model is then reevaluated and updated to reflect new understanding of the ecosystem.

An ecosystem is defined by living organisms and their physical environment, which interact in a regular and interdependent way to form a unified whole (Odum 1975). When we refer to the “Denali Ecosystem,” we look at the entire park, as if from space, and ask: What is occurring there? Do the physical and biological components of the 2.4 million hectares (6 million acres) called Denali National Park and Preserve interact in a regular and interdependent way to form a unified whole? If so, how do they interact? If not, what ecosystems comprise the park, or to what larger ecosystem does the park belong? We feel it is important to define what we mean by the Denali Ecosystem because the park is mandated to protect and preserve that ecosystem. Our conceptual model will be used to define what we mean by the Denali Ecosystem.

This conceptual modeling begins with a review of what we already know. Fortunately, Denali has a rich research history. What we present here—mainly a review of existing literature—is a first step toward building an ecosystem model for Denali. We need to create a synthesis of the information produced by that research, reducing the information to its most salient facts.

We first provide a short introduction to the Denali Ecosystem. We then present the four conceptual models with which we chose to start. Our approach to modeling is to begin by building many small models, rather than one all-encompassing model (Starfield 1997). The models we start with are descriptive of basic patterns in climate and vegetation, the basic types and characteristics of aquatic systems, and the general trophic relationships between plants and animals (i.e., who eats what). These models do not capture everything there is to know about the Denali Ecosystem, but they do provide basic information eventually leading to an understanding of the Denali Ecosystem. We conclude this chapter by considering the implications of some characteristics of the Denali Ecosystem to design of the monitoring program.

Introducing the Denali Ecosystem

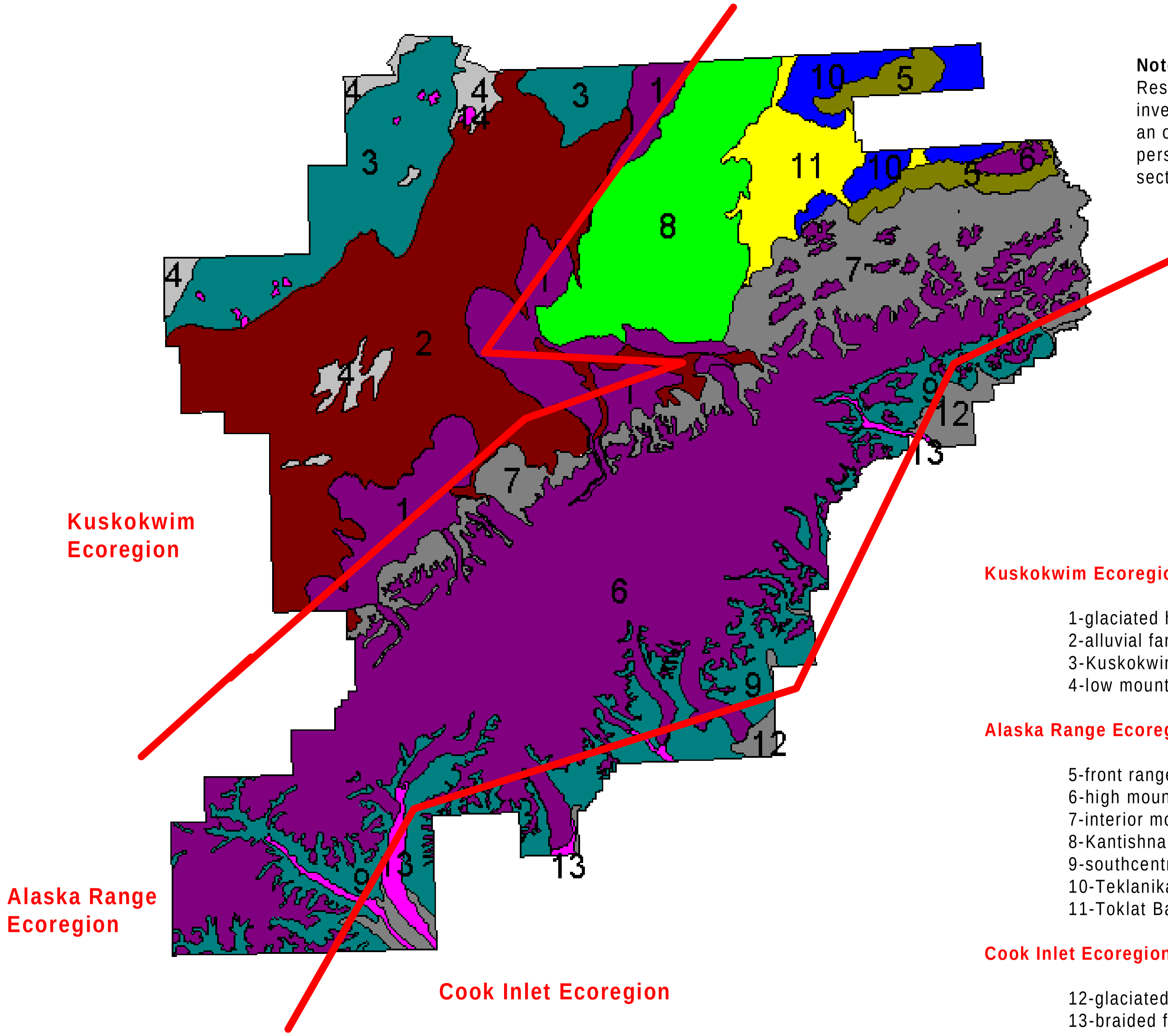
The dominant features of the Denali Ecosystem derive from its location. Denali is:

- subarctic, ranging between 62 and 64 degrees north latitude,
- bisected by the highest mountain in North America [Mount McKinley at 6,194 meters (20,320 feet)] and its associated mountain range, the Alaska Range, and
- continental (not near the ocean, though some of the climate is coastally influenced).

Because of its latitude, and because much of the park is near or above treeline, Denali spends most of the year covered with snow and lies within the region of discontinuous permafrost (perennially frozen ground). The growing season is short. Land cover includes vast unvegetated areas covered by glaciers, snow and ice, and rock. The vegetation consists of alpine tundra and taiga communities. Fires, generated by summer lightning storms, burn large patches creating a mosaic of vegetation types, especially in the expanses of taiga forest in the northwestern section of the park. Because of its mountainous nature, the rivers and streams in the park are mainly headwater streams, many of which are glacial in origin. Many such streams are broad, braided glacial rivers. The mountains also divide the park into two distinct climatic zones, a continental climate, and a transitional maritime climate. The animals of Denali either adapt specifically to survive the long winter (e.g., hibernation, special food storage mechanisms), or they migrate. Thus, the animals present in the Denali Ecosystem differ considerably between winter and summer.

Flying over the vast expanse of Denali, one can readily see major north-south and east-west differences in the landscape. A NPS project, conducted in cooperation with the U.S. Natural Resources Conservation Service, to identify and map these differences in terrain using ecological criteria is currently underway. These landscape units with similar ecological features are called ecoregions. Preliminary ecoregions for Denali (see Figure 5) are defined based primarily on lithology (the underlying geology) and climate (Mark Clark, U.S. Natural Resources Conservation Service, pers. commun.) Under this schema, Denali falls into three ecoregions: (1) *Kuskowkim*, (2) *Alaska Range*, and (3) *Cook Inlet*. The *Kuskokwim* ecoregion is composed of plains and low mountains. The *Alaska Range*

Figure 5: Ecoregions and Sections of Denali National Park and Preserve



Note: Draft map developed by the USDA-Natural Resources Conservation Service in 1998 to support an inventory of Denali soils. A revised ecoregion map will be an outcome of that inventory project (Mark Clark, NRCS, pers. commun.). Polygon numbers 1-13 represent sections within each ecoregion.

Kuskokwim Ecoregion

1-glaciated hills and pitted plains
2-alluvial fans and flood plains
3-Kuskokwim-Minchumina Basin
4-low mountains and pediments

Alaska Range Ecoregion

5-front range
6-high mountains
7-interior mountains and glaciated valleys
8-Kantishna Hills
9-southcentral mountains
10-Teklanika Mountains and plateaus
11-Toklat Basin

Cook Inlet Ecoregion

12-glaciated hills and plains
13-braided flood plains and stream terraces

ecoregion is mountainous and topographically complex. The *Cook Inlet* ecoregion portions of Denali include the hills and river bottoms and terraces that descend from the southern flanks of the Alaska Range.

The Denali Ecosystem of today is likely much the same as it was 6,000 years ago (Elias 1995)[2]. Until the beginning of the twentieth century, when Europeans entered the region in significant numbers, the area that became Denali National Park and Preserve was used by five bands of Athabaskan Indians. The permanent villages of these bands were most likely located outside what is now the park, but the residents visited the area to hunt, especially caribou, moose, and sheep. In the early 1900s, traditional uses by Athabaskans began to be usurped by such activities as mining and commercial hunting and trapping. The establishment of the park in 1917 stopped or slowed this resource development trajectory.

We proceed now to more specific discussions of the models we chose to start with in building an overall conceptual model of the Denali Ecosystem. These initial models describe general patterns of climate, vegetation, aquatic systems, and trophic relationships.

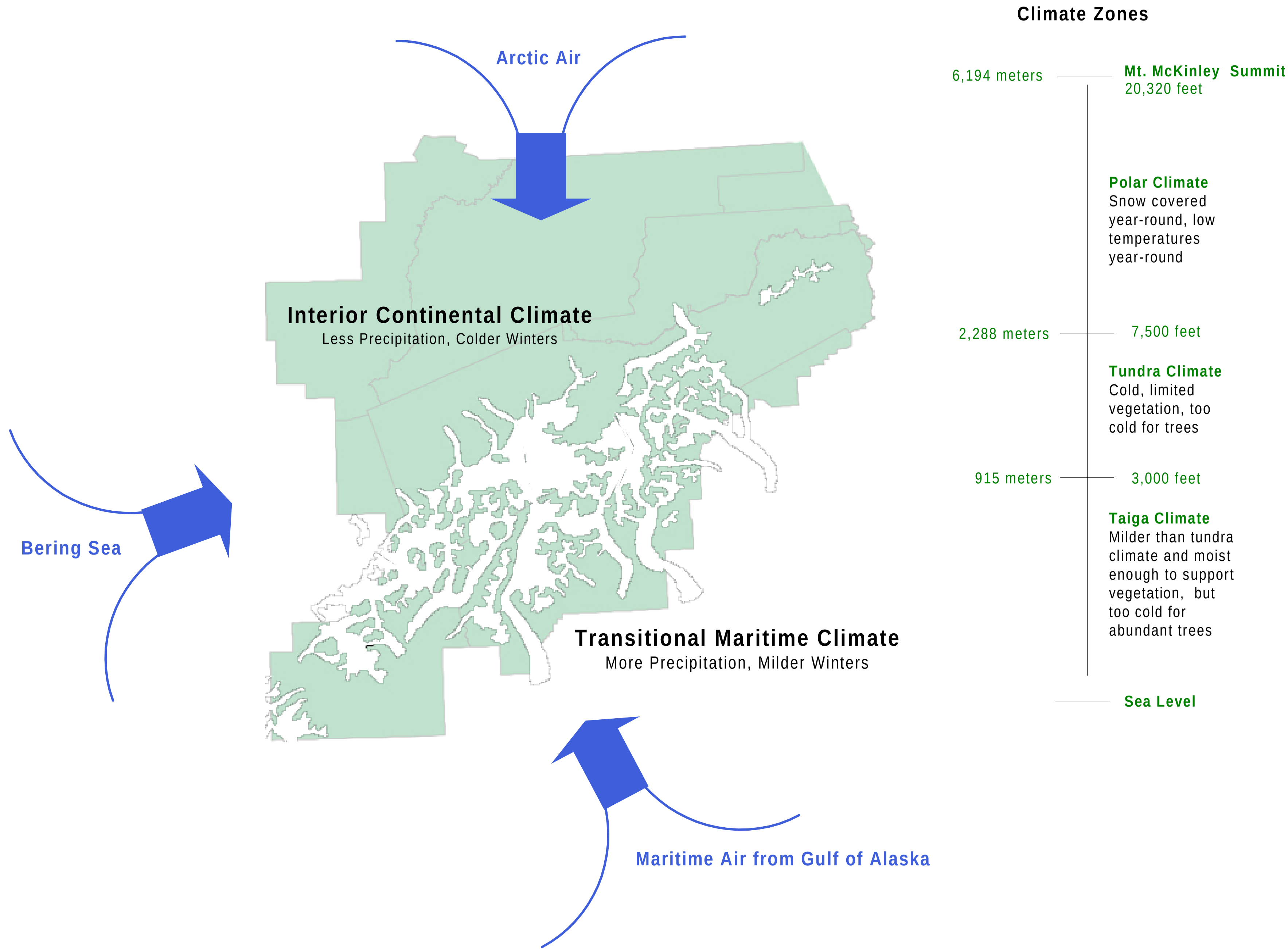
Climate

Climate has a dominant influence on the ecology of Denali. An understanding of the key relationships affecting climatic patterns therefore plays a pivotal role in the overall ecosystem model. A graphic depiction of our generalized climate model is shown in Figure 6.

The central features of the landscape that drive the weather of Denali are Mount McKinley and the Alaska Range. Mount McKinley, at 6,194 meters (20,320 feet) above mean sea level, is the highest point in North America and has some of the most severe weather in the world. The elevation extremes within the park contribute to the complexity of meteorological conditions.

2. Prior to that, the Denali area was dominated by steppe-tundra vegetation, reflecting a cooler and drier climate. About 13,000 years ago, Northern Hemisphere climates began to warm, and birch (*Betula*) shrub tundra became established. About 9,000 years ago, spruce (*Picea*) invaded southcentral Alaska, spreading rapidly in Interior Alaska north of the Alaska Range.

Figure 6: Generalized Climate Model for the Denali Ecosystem



The landscape above 2,288 meters (7, 500 feet) remains permanently snow covered.

The extreme range in elevations found in the park affects air temperature and precipitation patterns, creating taiga, tundra, and polar climate zones. The taiga climate zone receives rain in summer and snow in winter; the taiga zone is milder than the tundra zone and moist enough to support vegetation, but too cold for abundant tree growth. The tundra zone receives snow year round, wet in summer and dry in winter, and remain too cold to support tree growth. The polar zone receives only dry snow, and temperatures remain below freezing year round.

The Alaska Range influences climate by blocking moisture that sweeps inland from the Gulf of Alaska, acting as a barrier between the maritime weather of the south and the continental interior. The south side of the park has a transitional maritime climate, which is warmer and wetter than the continental climate of the north side. The south side receives much more precipitation and experiences fewer extremes in temperature. On the north side, with its continental climate, much less snowfall occurs, with mild summer temperatures and extremely cold winter temperatures. Temperatures in winter on the north side of the Alaska Range can reach minus 51 degrees Centigrade (minus 60 degrees Fahrenheit) during high-pressure, low-wind events. Thunderstorms are regular features of summer weather on the north side of the park. Lightning strikes that accompany these thunderstorms often cause wildfires, which are one of the most important forms of disturbance in the boreal forest.

Wind is also an important feature of Denali weather, especially at higher elevations. Chinook winds coming over mountain passes from the south generally bring warm, moist air. These periods of low pressure often result in substantial amounts of precipitation on the windward (south) side of the range. Chinook winds also can bring precipitation up and over the passes, dumping rain and snow on the north side of the range. Chinook winds are noticeable especially in the winter when temperatures can rise in excess of 27 degrees Centigrade (50 degrees Fahrenheit) in a few hours. Most of the winter snow accumulation on the north side of the park occurs because of these events. These winds often are characterized by higher wind speeds, gusting in canyons and river valleys to speeds exceeding 64 kilometers per hour (40 mph). In contrast, the winds that blow from the north are relatively calm. However, north winds often occur when air temperatures are subzero, so wind chill makes the temperatures seem lower.

This generalized climate model is a foundation to enhance our understanding of the role weather plays in the Denali Ecosystem. Further development of the model to aid monitoring program design is needed in two specific but related areas: (1) the influence of synoptic weather patterns, and (2) response to global warming.

While we have a general understanding of the temperature-precipitation patterns across the range of elevations and latitudes within the park, we have not yet developed our understanding of the synoptic weather patterns driving the conditions in Denali. Conditions in the northern Gulf of Alaska (El Nino and the Pacific Decadal Oscillation), the Arctic (the Arctic Oscillation), and in the Bering Sea probably have determining effects on Denali weather. With the long-term weather records available from park headquarters for the past 75 years, we can look for patterns between the weather of Denali and these larger-scale phenomena. A better understanding of the synoptic influences is important because Denali is subject to influences beyond its boundaries due to atmospheric circulation patterns. Specific concerns, discussed in Chapter 5 *Resource Preservation Concerns*, are Arctic Haze, long-range transport of contaminants from Eurasia, ozone depletion, and increased ultraviolet radiation.

The climate model also needs further development to consider potential responses to global warming. Based on weather data from park headquarters, a distinct warming trend has occurred, beginning in the late 1970s (Juday 2000). This warming trend is consistent with observations in Fairbanks. This warming trend[3] obviously has important implications for the Denali Ecosystem. Warming will affect many of the features that play a critical role in the Denali Ecosystem, including distribution of permafrost, glacier and river dynamics, ice formation on lakes and rivers, overall vegetation patterns and especially the location of treeline

3. Summer and mean annual temperature increased 1.3 degrees Centigrade (2.3 degrees Fahrenheit) since 1976, a substantial warming.

and frequency and size of wildfires. Building on the Denali climate model, we can predict the range of likely responses to warming at the park, using the tremendous amount of work done by others on global warming (e.g., Starfield and Chapin 1996, AMAP 1998, Rupp 1999, EPA 2000).

Because weather has such a profound influence on all aspects of Denali ecology, the expansion of the Denali climate model to include synoptic influences and to predict responses to continued warming will help our overall monitoring effort. Our ability to understand responses of vegetation, aquatic systems, and wildlife to synoptic influences and sustained warming will depend on first predicting how climate is and will be affected.

Vegetation

Many influences control vegetation in Denali, such as interactions of climate, topography, substrate, site history (and disturbance events) and living organisms, including plants, fungi, symbionts (lichens and mycorrhizae) and herbivorous animals. The influence of these determining factors varies greatly across the Denali landscape. Thus, we find a mosaic of plant communities and vegetation types that vary across spatial scales. The mosaic includes patterns due to micro-topography within individual sites to patterns on the scale of the landscape that are driven by regional climate.

As noted, Denali is located between 62 and 64 degrees north latitude. This area of the earth's surface lies within the taiga, or northern boreal forest biome. As such, Denali is predominantly forested below elevations of about 763 meters (2,500 feet), although local treeline varies with topography and location. Above treeline, we find two other vegetation zones: subalpine and alpine. In the subalpine zone [generally located between 763 meters (2,500 feet) and 1,068 meters (3,500 feet)], scrub vegetation, consisting mainly of tall shrubs, interspersed with open white spruce (*Picea glauca*) woodland, dominates. In the alpine zone, tundra is found. The alpine zone is generally found above 1,068 meters (3,500 feet) and extends upwards to the polar zone, beginning at about 2,288 meters (7,500 feet), where the limits of plant life are met. As for treeline, the exact boundaries between the subalpine, alpine, and polar zones strongly depend on topography, site history, and local variations in climate.

Recognizing the main species and driving forces acting within these three vegetative zones is a prerequisite to understanding the role of vegetation in the Denali Ecosystem. Below, we present brief characterizations of each zone. We then briefly review past research on plants and plant communities in Denali, the importance of herbivory, and landscape scale patterns.

Forested Zone

Black spruce (*Picea mariana*) forest and woodland occupies areas underlain by permafrost, mostly north of the Alaska Range crest. Cold soil temperatures and poor drainage found in these sites result in relatively low annual productivity and slow growth. Black spruce stands burn periodically, and trees of more than 100 years of age are uncommon (Viereck et al. 1992). Black spruce is a fire-adapted species, with serotinous cones that generally require fire for seed dispersal.

River corridors and upland areas with better drainage support more productive forest types than sites with permafrost, because of higher soil temperatures and increased nutrient availability. White spruce forest occupies uplands, sometimes mixed with paper birch (*Betula papyrifera*) on hillsides. White spruce also requires a mineral seed bed for establishment, so recruitment of trees is generally tied to disturbance events, most frequently fire (particularly north of the Alaska Range).

Dry and open sites in the forested zone of Denali often have high cover of kinnikinnik (*Arctostaphylos uva-ursi*), raspberry (*Rubus idaeus*), and soapberry (*Sheperdia canadensis*). In southerly aspects, spruce forest is gradually replaced by aspen woodland with increasing slope. Aspen forest is characteristic of warm, relatively steep slopes on the north side of the Alaska Range, and is much less common on the south side, where balsam poplar (*Populus balsamifera*) occupies the warmer slopes.

The warmest and driest sites within the forest zone on the north side of the park are occupied by dry steppe-like vegetation dominated by grasses, sagebrush (*Artemisia* spp.), scattered shrubs of juniper (*Juniperus communis*), and a variety of herbaceous perennials. Equivalent sites on the south side of the Alaska Range are more likely to support lush graminoid-forb meadows dominated by Nootka lupine (*Lupinus nootkatensis*), geranium (*Geranium erianthum*), cow parsnip (*Heracleum lanatum*), and sedges (*Carex* spp.), due to moister growing conditions and historical factors.

Terraces along the major rivers support colonial herbs in newly abandoned channels grading into thickets of alder (*Alnus crispa*) and willow (*Salix* spp.). Older surfaces support mature balsam poplar forest grading into closed white spruce forest. Black spruce and mixed black-and-white spruce forest occupy areas where permafrost has developed and drainage is poor.

Interspersed within the forested zone on both sides of the Alaska Range are numerous wetland and riparian areas dominated by herbaceous taxa, including sedges, rushes, grasses, forbs, and mosses. Wetlands in Denali are often topographically controlled, that is, they occupy depressions, thaw features, and sites with poor drainage. Numerous ponds and wetlands dot large areas underlain by glacial till of Wisconsin age and represent relicts of kettle ponds formed as glacial ice retreated with strong climatic warming through the Holocene. Beaver (*Castor canadensis*) also have a considerable influence on the distribution of wetlands through the impounding of streams, particularly in the forested lowlands of the Cook Inlet and Kuskokwim ecoregions.

Subalpine zone

In the subalpine zone, roughly 762 meters (2,500 feet) to 1,220 meters (4,000 feet) in elevation, scrub vegetation dominated by dwarf birch (*Betula nana*), alder (*Alnus crispa*) and willow (*Salix* spp.) alternates with open spruce woodland and meadow sites depending on drainage, topography and site history. As the upper elevational limit of trees is approached, spruce woodland becomes very open and has higher relative cover of tundra shrubs.

The subalpine zone south of the Alaska Range crest, particularly in the Kahiltna and Yentna River drainages, is dominated by dense thickets of alder (*Alnus* spp.), devil's club (*Echinopanax horridum*), and other shrubs of more coastal distribution. The vegetation in these areas is considerably denser than equivalent sites north of the Alaska Range.

Alpine Zone

The alpine zone occupies elevations above about 1,068 meters (3,500 feet). The alpine vegetation of Denali is tundra, most often dominated by dwarf shrubs of the families Rosaceae and Ericaceae, as well as graminoids and forbs. Due to active geomorphic processes such as rockfall, and the relatively young age of surfaces in the alpine zone, many slopes are essentially barren, supporting only a few scattered cushion plants. The upper limit of plant growth is about 2,286 meters (7,500 feet), and elevations above 2,439 meters (8,000 feet) are mostly heavily blanketed by glacial ice.

Plant communities in alpine tundra are variable within Denali, depending on site characteristics and geographic location. Moisture is an especially important determinant in the plant community found on any particular alpine site. Where topography and wind patterns act to create late-lying accumulations of snow, the cool and moist conditions support unique snowbed plant communities. On drier sites, where there is no snow pack to extend the period of water availability, dwarf scrub-sedge tundra is found. On the driest sites are found graminoid-forb and *Dryas*-graminoid-forb associations, depending on slope, aspect, substrate, and slope morphology. These xeric (dry) alpine plant communities in Denali harbor numerous endemic plant species.

Past Vegetation Studies

Past work on Denali vegetation includes botanical expeditions, primarily along the park road, and a number of site and topic-specific studies. These include studies of altitudinal zonation (Shelton 1962), successional patterns following deglaciation (Viereck 1966), balsam poplar ecology (Lev 1987), methods for assisting restoration of disturbed areas (Densmore 1994, Karle and Densmore 1994), effects and recovery from trampling by hikers (Stelmock and Dean 1979), and effects of road dust and palliatives (Furbish 1996). Recent work includes specific efforts to improve the inventory of vascular plant species (Roland 1998) and monitoring of vegetation plots and spruce growth and reproduction in the Rock Creek drainage as part of the LTEM program (Roland 1999).

Herbivory

Herbivory is an important factor in the Denali Ecosystem. Animals that eat plants can have important influences on plants, effects which become evident in community processes. Many wildlife studies in Denali have examined use of vegetation and vegetation patterns important to herbivorous and omnivorous wildlife. These include food habits and habitat studies of caribou (Boertje 1981, Heebner 1982), Dall sheep (Whitten 1975), moose (Wolff and Cowling 1981, Risenhoover 1986, Van Ballenberghe et al. 1989, Risenhoover 1989, Miquelle and Van Ballenberghe 1989, Van Ballenberghe et al. 1992,), and grizzly bears (Valkenburg 1976, Stelmock and Dean 1986, Darling 1987). These wildlife studies have identified the plants in the Denali Ecosystem whose parts have particular importance as food for animals. These plants, and their parts, include:

- leaves and twigs from willows, especially *Salix alaxensis* and *S. planifolia* ssp. *pulchra*;
- berries from various shrub species, such as blueberry (*Vaccinium* uliginosum, cranberry (*Oxycoccus microcarpus* or *Vaccinium oxycoccus*), crowberry (*Empetrum nigrum*) and soapberry;
- lichens;
- spruce seeds;
- stems, shoots and roots from a variety of herbaceous plants, such as sedges (*Carex*), grasses (*Arctagrostis*), legumes (*Hedysarum)*, and horsetail (*Equisetum*);
- bark, phloem and leaves from deciduous trees (aspen, birch and poplar); and
- aquatic plants.

An herbivory model, linking the vegetation model to the food web model, would allow us to understand feedback between herbivores and vegetation.

Landscape Patterns

Our ability to get a bird's eye view of Denali vegetation to see landscape scale patterns has been stymied for many years by the lack of cloud-free satellite images. Early attempts (in the late 1970s) to map the land cover and vegetation of Denali using remote sensing were made by Rohde et al. (1978) and Dean and Heebner (1982). These efforts helped reveal the heterogeneity in Denali vegetation patterns.

Obtaining cloud-free images of Denali in the growing season has remained problematic. Currently, the NPS is using a multi-year mosaic of images to develop a current vegetation map (Jess Grunblatt, NPS, pers. commun.) This mapping effort also intends to describe the mapped classes to Level 5 in the Alaska Vegetation Classification (Viereck et al. 1992). Level 5 provides the highest level of detail about the community, including the main species in the overstory and understory (as appropriate).

This brief description of Denali vegetation needs to be expanded to address additional topics. These include: (1) the most common successional sequences following disturbance, specifically those following fire in the taiga and floodplain succession in areas below treeline and in the broad, braided glacial rivers, (2) treeline, and (3) decomposition processes. Linking the expanded climate model predicting trajectories of change due to climatic warming will be critical for predicting changes in vegetation. A recent study of tree ages in the park headquarters area indicates that treeline has been advancing in the park for about the past 150 years, coincident with warming since the Little Ice Age ended in 1850 (Juday 2000). Changes in treeline reflect changes in the broad distribution of the main vegetation zones (forests, subalpine, and alpine), which has many important ramifications, including those on wildlife.

Aquatic Systems

Denali includes many rivers, streams, lakes, ponds, and wetlands. These aquatic environments generally serve as nodes of productivity within the landscape and thereby form an important part of the Denali Ecosystem. Researchers have conducted several studies on the rivers and streams of Denali, allowing us to describe key relationships. Less is known about the lakes and wetlands of Denali.

Because Denali is mountainous, its rivers and streams are mainly headwater types. They range from highly turbid, glacier-fed rivers to small, groundwater-fed streams. The Alaska Range, as the dominating geographic feature of the park, divides the park into two hydrologic units, Yukon and Southcentral. On the north side of the range, rivers and streams flow into the Yukon River; on the south side, they flow into Cook Inlet. Rivers and streams within a hydrographic unit are similar in hydrograph (variations in flow during the year) and length of the ice-free period, except for glacier-fed rivers, which have a similar hydrograph across all hydrologic regions (Milner et al. 1997). Depending on elevation and aspect, streams experience a similar number of degree-days and have similar riparian vegetation.

Depending on whether streams are north or south of the Alaska Range, Denali streams also differ in their chemistry, due to differences in underlying geology (Edwards and Tranel 1998). On the north side, marine sediments containing abundant and easily weathered carbonaceous rocks dominate the geology. Thus, stream waters are highly alkaline (pH greater than 7.0) and well buffered. They also have higher conductivity due to higher ionic concentrations. On the south side, acidic rocks of volcanic origin called plutons, which are more resistant to weathering, dominate the geology. These streams are also alkaline, but pH values, buffering capacities, and conductivity, are lower than on the north side.

The influence of these chemical differences of north side and south side streams is not clear. Conn (1998), examining the benthic macroinvertebrate fauna of Denali streams as part of the Denali LTEM program, did not find distinct differences in the fauna between north side and south side streams. Channel stability, more than any other factor, determined abundance and diversity of stream macroinvertebrates. In general, diversity of invertebrates in Denali streams is low—only 26 taxa have been found.[4] Non-biting midges (Chironomidae) dominated the fauna. Other important taxa were mayflies (Ephemenoptera), stone flies (Plectoptera), caddis flies (Trichoptera), and oligochaete worms.

Based on invertebrate community structure, Conn (1998) distinguished six major stream types in the Cook Inlet and Alaska Range ecoregions of Denali. This stream classification integrates water source, underlying geology, hydrological regimes and

4. In contrast, streams in temperate latitudes might have 200 or more taxa.

vegetation characteristics, providing a watershed stratification. The six types are:

- *Clearwater Rivers*: Small, first-to-third-order rivers characterized by a stable channel and riparian zones with abundant growth of alder and willow trees.
- *Spring-fed Creeks*: Small creeks, with a high degree of channel stability and a close border of riparian vegetation that in some reaches shades much of the channel.
- *Kantishna Rivers*: Second- and third-order rivers located in Kantishna and the northwestern area of the park. These rivers have a well-developed riparian zone and support the greatest diversity of benthic macroinvertebrate fauna of all the stream types.
- *Large, Unstable Rivers:* Larger rivers with unstable channels, some of which have slight glacial meltwater influence.
- *Small, Unstable Creeks*: Small, first- and second-order creeks with high gradients and actively migrating channels in which water flow responds rapidly to summer precipitation events.
- *Glacier-Fed Rivers*: Rivers fed by glaciers and with highly unstable channels. These systems support a low abundance and diversity of macroinvertebrates.

The low diversity of invertebrate taxa within Denali streams makes some of the multimetric techniques commonly used to evaluate stream health in lower latitudes inappropriate for use in evaluating Denali streams (Conn 1998). However, the strong relationship between physical and chemical characteristics of a stream and the invertebrates residing in the stream allows the development of a predictive model where the observed community can be compared with the predicted community (Conn 1998). This relationship provides park managers with a tool for evaluating the status of macroinvertebrate communities in its streams. Because macroinvertebrate communities reflect water quality and other stream parameters, their status is commonly used to infer the ecological health of streams.

In contrast to our understanding of invertebrate distribution in Denali streams, our understanding of fish distribution and abundance is relatively limited. The only formal studies of Denali fish are those of Miller (1981), who inventoried fish in streams crossing the park road, and Meyer and Kavanaugh (1983), who studied fish in placer-mined streams near Kantishna. Miller (1981) found only five species of fish: Arctic grayling (*Thymallus arcticus*), dolly varden (*Salvelinus malma*), lake trout (*Salvelinus namaycush*), chinook salmon (*Oncorhynchus tshawytscha*), and unidentified sculpins (Cottidae). Grayling are the most widely distributed and abundant fish in Denali, and are presumably common in the clearwater stream types described by Conn (1998). Salmon spawn in rivers and streams on the south side of the park, and park waters presumably also provide rearing habitat. Miller (1981) found young king salmon rearing in Kantishna streams. Major spawning concentrations of chum salmon (*Oncorhynchus keta*) also are found in certain drainages on the north side. These salmon, which have come more than a thousand kilometers up the Yukon River, spawn late in the fall. These concentrations feed birds, bears, wolves, and undoubtedly other species at a critical time of year when other food sources have dwindled.

The attraction of animals to spawning salmon in streams is an example of how streams serve as nodes of high productivity within the Denali landscape. Riparian vegetation such as willows are important to moose and other browsers. Certain species of birds, such as dippers (*Circlus mexicanus*), Harlequin Ducks (*Histrionicus histrionicus*), and Wandering Tattlers (*Heteroscelus incanus*), are found along productive streams. Insect diversity and abundance also are likely higher in riparian areas (Bonanza Creek LTER, unpublished data), attracting insectivorous birds, mammals and insects. The roots of *Hedysarum alpinum*, a leguminous species that grows on gravel bars, are often the first food of grizzly bears in the spring before other foods become available.

The lakes, potholes, and wetlands of Denali likely are equally important nodes of productivity in the landscape. However, these parts of the aquatic system of Denali have received almost no study. Within the low-lying *Kuskokwim* ecoregion are hundreds of small lakes and kettle ponds. Trumpeter swans (*Cygnus buccinator*) and many species of ducks nest in these areas, which also provide homes for beavers and muskrats (*Ondatra zibethicus*).

Within its aquatic systems are found the parts of the Denali Ecosystem that have been the most affected by human activities.

Extensive placer mining for gold and lode mining for antimony occurred in the Kantishna region during the early twentieth century. The placer mining techniques severely affected the channels and riparian areas of many streams. While the Kantishna area was not included within the original park boundaries, the area was added in 1980 by ANILCA. Mined streams in the Kantishna Hills were studied to determine their condition (Deschu 1985, Van Maanen and Solin 1988, Oswood and Wedemeyer 1990). Eventually, steps were taken to restore channels and riparian areas of selected streams (Karle and Densmore 1994, Karle et al. 1996, Major 1996). Further work is planned.

Food Web

A food web model (Figure 7) showing who eats what makes a useful starting point to understand the key relationships among the plant and animal species in the Denali Ecosystem. To prepare this model, we compiled literature on food habits of Denali animal species, using studies done in Denali or nearby as the primary sources of information. This food web integrates trophic relationships over the entire year. Separate food webs could be constructed for winter and summer, as many of the animals present in summer are absent, via migration or hibernation, during the winter.

As for any ecosystem, the primary producers form the foundation. At Denali, these include a variety of herbaceous plants, shrubs, and both deciduous and coniferous trees. The herbivores that consume these plants are mainly mammals and insects, and to some extent, birds. The mammalian herbivores range from large moose to tiny mice, and each size class of herbivore supports a different suite of mammalian and/or avian predators. The terrestrial invertebrate component of the ecosystem (mainly insects and spiders) appears to be the main support for passerine birds, but this component of the ecosystem is has not been studied and therefore is not well understood. Aquatic productivity is presumably related to production of both algae and litter from deciduous trees and shrubs. Animals in the aquatic systems include invertebrates, fish, birds and mammals.

The Denali Food Web helps identify the main players in the biological system and shows their general relationships, revealing the main interaction webs. Interaction webs represent the subsets of species in a food web that interact strongly through both trophic and nontrophic relationships (Menge 1995). Recognizing and naming these interaction webs provides a foundation for integrating nontrophic information that is also important in the relationships (e.g., snow depth is a critical factor in the wolf-ungulate interaction web).

We have divided the Denali Food Web into seven interaction webs. For convenience, the interaction webs are named—we admit arbitrarily—for one of the species at the top or in the middle of the interaction web. An overview of these interaction webs is provided below.

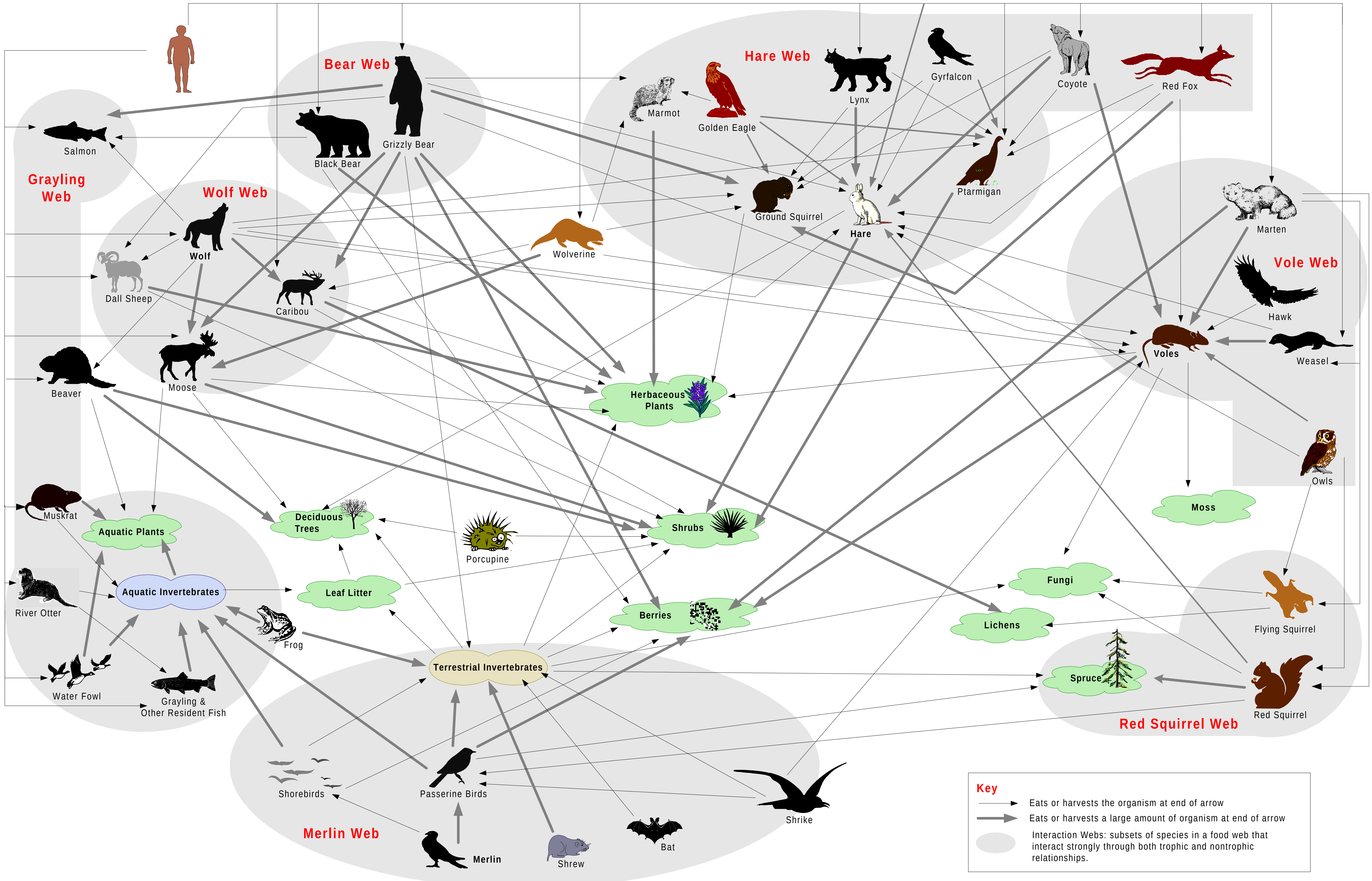
Wolf Web

This interaction web includes wolves, their primary ungulate prey (caribou, moose, sheep), and their plant foods, primarily shrubs, herbaceous plants, and lichens. Denali wolves eat a variety of other species, including beavers, salmon, voles, marmots (*Marmota caligata*) and arctic ground squirrels (*Spermophilus parryi*). Carcasses of ungulates killed by wolves are consumed by many other species. Humans are part of the Denali *wolf web*, through trapping of wolves, and hunting of caribou, moose, and sheep. Public interest in Denali wolves and their ungulate prey has always been high, and the members of the *wolf web* at Denali have been and continue to be the subject of intensive research and monitoring (Murie 1944, Whitten 1975, Murphy and Whitten 1976, Wolff and Cowling 1981, Boertje 1984, Singer and Dalle-Molle 1985, Risenhoover 1986, Singer 1986, Risenhoover 1989, Van Ballenberghe et al.1989, Boertje 1990, Rachlow and Bowyer 1991, Adams et al. 1995, Adams and Dale 1998a, b, Mech et al. 1998, Burson et al. 1999).

Bear Web

The *bear web* includes grizzly and black bears (*Ursus americanus*). These species are omnivores, relying on both plant and animal foods. The plant foods of bears include different plants than those eaten by the ungulate prey of wolves, thus the foundation of the *bear web* differs from the foundation of the *wolf*

Figure 7: Denali Ecosystem - Who Eats What?



web. The most important plant foods of bears are the shoots or roots of herbaceous plants (especially *Hedysarum alpinum*, *Equisetum*) and berries. Denali grizzly bears primarily eat plants, but also pursue arctic ground squirrels, the young calves of caribou and moose, and wolf-kill carrion. By hunting bears, humans also are part of the Denali *bear web*. The grizzly bears of the north side of Denali have been fairly well studied (Valkenburg 1976, Tracy 1977, Murie 1981, Singer and Beattie 1986, Darling 1987, Dean 1987, Stelmock and Dean 1986, J. Keay, USGS, unpublished, Burson et al. 1999). Grizzly and black bears on the south side of the park are the subject of an ongoing study (Jerry Belant, NPS, unpublished).

Hare Web

The *hare web* includes the predators [golden eagles (*Aquila chrysaetos*), lynx (*Felis lynx*), gyrfalcon (*Falco rusticolus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*)] that rely on mesoherbivores [ground squirrels, snowshoe hares (*Lepus americanus*), and willow ptarmigan (*Lagopus lagopus*)], and plant foods, primarily shrubs and herbaceous plants, eaten by the herbivores. Populations of snowshoe hares and willow ptarmigan are cyclic. These cycles are believed to relate to production of anti-herbivory compounds by shrubs (mainly willows), which are the mainstay of their diets (Bryant et al. 1985). Because lynx rely primarily on hares for food, lynx populations are also cyclic. Golden eagles are the only member of the *hare web* that have been extensively studied at Denali (McIntyre 1995, McIntyre and Adams 1999, C. McIntyre, NPS, ongoing studies). The eagle studies also have generated annual indices of abundance for hare and willow ptarmigan populations (McIntyre and Adams 1999).

Vole Web

The *vole web* includes predators that rely on voles (miniherbivores), and their plant foods. The red-backed vole is the most abundant and widespread of the voles. Several species of *Microtus* also occur (Murie 1994). Voles primarily eat herbaceous plants and berries (West 1982). Many predator species rely on these small mammals, including wolves, red fox, weasels (*Mustela erminea, M. nivalis, M. vison*), marten (*Martes americana*), coyotes, hawks, and owls. Humans trap the furbearer species that eat voles and thus form a part of the *vole web*. Monitoring small mammal populations has been a part of the Denali LTEM program since 1992 (Rexstad 1994, Furtsch 1995, Oakley et al. 1999, Rexstad and Debevec 1999a, b). Vole populations in Denali can vary by an order of magnitude between years (Rexstad 1994). Denali-based studies of the variety of predator species that rely on voles have not occurred.

Red Squirrel Web

Several species, including red squirrels (*Tamiasciurus hudsonicus*), flying squirrels (*Glaucomys sabrinus*) and White-winged Crossbills (*Loxia leucoptera*), have specialized food habits tied to the spruce forest. Spruce seeds provide the main food of red squirrels (Brink and Dean 1966, Nodler 1973, Kelly 1978). Annual spruce seed production is highly variable with years of bumper crops and years of complete crop failure (Smith 1968). To address the high variation in food supply, red squirrels store massive quantities of seeds. Red squirrels also can be carnivorous, eating nestlings of birds and young snowshoe hares. Flying squirrels are also tied to the forest but do not rely on spruce seeds; they eat primarily fungi and lichen (Maser et al. 1985). Flying squirrels are apparently critical to the dispersal of spores of ectomycorrhizal fungi. This connection between flying squirrels and mycorrhizal fungi has implications for the productivity of spruce. The squirrels of Denali have not been specifically studied nor have mycorrihizae in forested zones. Studies of white spruce growth and reproduction (i.e., cone and seed production) have been included in the Denali LTEM program since 1992 (Roland 1999). Except for studies of cellular slime molds (Landolt et al. 1992), the fungi of Denali have not been well-studied. A lichen checklist was published by Weber and Viereck (1967).

Merlin Web

Merlins (*Falco columbarius*) are falcons that prey primarily on passerine birds that eat insects. The *merlin web* describes the part of the Denali Food Web that is linked primarily by passerine and other birds and their terrestrial arthropod prey. Merlins have been studied at Denali (Laing 1985, Wilbor 1996). The Denali LTEM program has included monitoring of passerine bird populations, including the relative abundance and productivity of the main species eaten by merlins (e.g., Paton and Pogson 1996, Froelich et al. 1998). The terrestrial arthropod species that are central to this web, and their trophic relationships, have not been described. Werner's (1983) description of arthropod-plant community relationships in taiga near Fairbanks is probably generally applicable to the taiga communities of Denali. The arthropods of Denali's tundra regions are unstudied. Saprovorous arthropods are important to decomposition cycles, which is another aspect of the Denali Food Web that is largely unknown.

Grayling Web

As described in the *Aquatic Systems* model, the aquatic environment of Denali includes rivers, streams, lakes, potholes, and wetlands. Productivity of the *grayling web* depends upon primary producers that live in the water (mainly algae) and the deposition of leaf litter from riparian vegetation, primarily deciduous trees and shrubs. Aquatic invertebrates and fish are the primary consumers; the diversity of consumers is low. Various birds (mainly waterfowl, a few shorebirds, and dippers) also are part of the *grayling web*. The primary mammals involved are muskrat and beavers. Wolves, bears, and other mammals consume spawning salmon, linking marine production with the aquatic and terrestrial ecosystems of Denali. Humans are a part of the *grayling web* via their consumption of fish and trapping of aquatic furbearers (muskrat and beaver).

Implications for the Monitoring Program

As stated earlier, monitoring programs must match the ecosystem being monitoring. Having now described our conceptual model of the Denali Ecosystem, we can ask: what implications do Denali Ecosystem characteristics have for monitoring?

Three themes emerge. The first is the central role of Mount McKinley and the Alaska Range in dividing the park into two distinct areas. Little is said or written about the Denali Ecosystem that does not include a caveat about whether one talks about the north side or the south side of the park. Similarly, when one talks about the north side of the park, one must differentiate between the flat lands of the Kuskokwim basin and the front ranges of the Alaska Range. For monitoring, the three ecoregions provide logical units for integrating monitoring information, and possibly for allocating monitoring effort.

The second theme that emerges is the explicit recognition of humans as a part of the Denali Ecosystem. A review of the food web model illustrates the many portions of the food web where humans are involved. As a park with ANILCA additions, humans need to be considered an integral part of the ecosystem. In this respect, Denali and other national parks in Alaska are unique from parks in other states.

The last theme that emerges relates to the high year-to-year variation found within certain components of the Denali Ecosystem, and the dynamic nature of the vegetative landscape due to succession following disturbance. For example, high annual variation is observed in spruce cone production, small mammal and stream invertebrate populations, and in reproductive success in many vertebrate species. The high degree of annual variation and the importance of vegetation succession affect our view of change, how we detect change through monitoring, and how we view the overall role of the monitoring program.

High annual variation and successional processes are perhaps intrinsic features of high latitude ecosystems. In these systems, detecting change between years can be easy, but what is its significance (Rexstad and Debevec 1999b, Rexstad and Debevec 1999c)? Because change is a strong feature of this ecosystem, we need to understand the range of variation in the magnitude of those annual changes. In monitoring parlance this is *process variation*, which is the variation observed in an ecological attribute due to environmental variation (Thompson et al. 1998). To determine whether a change is within the range of expected variation, we must be able to separate the process variation from the uncertainty introduced by sampling methods, or *sampling variation*. Thus, in our approach to monitoring the Denali Ecosystem, we are focusing on determining process variation in each of the attributes ultimately selected for repeated measurement. A good understanding of process variation is required if we want to detect, and ultimately act on, changes due to human factors.

Chapter 5
Resource Preservation Concerns

The purpose of this chapter is to define the management context of the Denali Long-term Ecological Monitoring (LTEM) program. The goal of the Denali LTEM program is to help park managers protect the resources of Denali by providing the ecological context for resource preservation decisions. Thus, we have designed the monitoring program with resource preservation decisions in mind.

We begin by highlighting the key values of Denali National Park and Preserve, which the day-to-day management decisions of the park strive to preserve. We briefly review past resource preservation concerns. We then consider the most important potential sources of significant adverse impact to the unique values of Denali National Park and Preserve, as identified in the Resource Management Plan (Denali National Park and Preserve 1998). These potential sources of impact, and our understanding of what adverse impacts they might cause to park resources, are central to the design of the monitoring program.

Key Park Values

We base selection of attributes to be monitored, in part, on our understanding of the ecosystem, and, in part, on their relationship with the key values of Denali National Park and Preserve. We introduced the key values of Denali earlier (Table 1). This listing of the key values of Denali has evolved over time and is derived from the Park's enabling legislation, boundary extension legislation, wilderness designation, the Alaska National Interest Lands Conservation Act, and management documents such as the 1986 General Management Plan, and the 1995 Statement for Management, and the Resource Management Plan (Denali National Park and Preserve 1998). The most recent statement of the key values of Denali is made in the Strategic Plan for implementation of the Government Performance and Results Act (Denali National Park and Preserve 1997b).

We must identify these key values explicitly, because they explain what is unique about Denali National Park and Preserve. It is these values that park management must work to preserve unimpaired for future generations. Of these key values, the long-term ecological monitoring program seems well suited to providing data that will help park managers make decisions to preserve (1) an intact subarctic ecosystem—that is unfragmented without major boundary effects, (2) plant life and wildlife (which cannot be separated from the first key value of an intact ecosystem), (3) pristine air quality, and (4) subsistence uses.

Past Resource Preservation Concerns

A review of the resource preservation concerns faced by Denali park managers since its establishment in 1917, provides perspective on potential future concerns. Brown (1993) covers the history of the park through the passage of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. A singular question emerges from Brown's presentation of park history:

> How to protect the park-refuge interior of the park while still providing public access?

This question has two related prongs. The first relates to wildlife and protection of wildlife. The other relates to public access and the park road.

Wildlife

A movement to stop market hunting of big game, primarily Dall sheep and caribou, became a major impetus to establish what was then called Mount McKinley National Park. Charles Sheldon, a naturalist-hunter, had visited the Denali region in 1907-1908 (Sheldon 1930). Sheldon became the main advocate for creation of the park, and his vision of Denali was as a park-refuge. Thus, the creation of the park was as much about protection of wildlife as it was the towering beauty of Mount McKinley.

Establishment of the park did not result in immediate cessation of hunting, however. One concession needed to establish the park was an allowance that Kantishna miners and trappers could continue to hunt within the park for their immediate needs. Hunting continued without any controls (the park had no money for enforcement) until 1928, when Congress repealed the hunting provision in response to mounting conservation pressure. Wildlife issues gained importance again when the Dall sheep population collapsed following a series of hard winters in 1927-1932. Adolph Murie was dispatched to the park in 1939-1941 to investigate whether the park should step in as big game managers and control wolves. Although Murie concluded that the sheep and wolf populations were in balance, pressure for the park to control wolf populations remained intense. In part to head off legislation that would have required that the NPS control wolves and other predators in favor of “game” animals, the NPS destroyed approximately 70 wolves in Denali between 1929 and 1952.

Another important wildlife issue in Denali has involved the management of bear-human interactions. Bear-human incidents rose dramatically in the 1970s as park visitation rose sevenfold (Dalle-Molle and Van Horn 1989). The park established a comprehensive management program that is successful in preventing and reducing encounters between humans and bears (Albert and Bowyer 1991, Schirokauer and Boyd 1998).

Complexity of park management was increased in 1980 when the boundaries of Denali were extended by ANILCA. The 1980 additions were made in large part to encompass more of the habitat of the Denali Caribou Herd. The additions also included two units of lands designated as preserves, where sport hunting would be allowed. The new park lands (and the preserve lands) also were opened to subsistence, including hunting and trapping. By allowing consumptive uses, the 1980 additions increased the complexity of protecting wildlife in Denali.

Denali wolves continue to be of high public interest, with two packs (i.e., the East Fork Toklat pack, and the former Headquarters pack) widely known by the public. The park is repeatedly asked to address concerns about wolves that reside mainly within Denali but who venture onto adjacent lands where they may be legally trapped or shot. Debate continues throughout Alaska over the use of wolf control to increase moose and caribou populations and concerns have increased about Denali wolves living near the park boundaries.

Access

The other recurring theme to Denali resource preservation concerns involves access to the park. The complexity of the access issue stems, in part, from the role the park has played in developing access to this region of the state. Construction of the park road was a partnership between the NPS and the Alaska Road Commission. Development of the park road was viewed as a benefit for the park (by providing access for park visitors), the Alaska Railroad (which would carry freight and passengers to the beginning of the road), and the Kantishna miners. Thus, the road was built to serve multiple purposes. Balancing management of the road to provide access for visitors and Kantishna inholders, while preventing impacts to park resources, continues to this day.

Considerable pressure to expand access to the park has been levied in recent years. In 1996, Congress mandated the park investigate the feasibility of a north access route (road or rail) that would enter the park in the Stampede area and traverse the northern addition to the Kantishna region (Denali National Park and Preserve 1997c). Denali park managers are currently working with the State of Alaska and other parties to plan south-side access. This is generally considered the best option for increasing visitor access without impacting park resources (National Park Service et al. 1997), although acceptance of the idea is not universal.

Current and Future Preservation Concerns

The Resource Management Plan (Denali National Park and Preserve 1998) describes current concerns and concerns considered to be significant sources of potential adverse impact in the park’s future. These are: Industrialization (Global, Regional and Local), Settlement, Access, Animal Harvest, Plant Harvest, and Mineral Extraction. We provide a general description of each concern below. Because the concerns are not isolated, we also develop a conceptual model of how the concerns relate to one another (Figure 8). This consideration draws on the Resource Management Plan but also on the results of the Denali LTEM program planning workshops held in July and October 1996.

Global, Regional, and Local Industrialization

The immediate area around Denali is rural and not industrialized. The most significant potential source of industrial pollutants locally is from local power generation at the park (diesel generators located at park headquarters, Toklat road camp, Eielson Visitor Center, and Wonder Lake Ranger Station), coal-fired power plants in Healy, and emissions from the Anchorage area, where most of Alaska's population resides. As the population of Alaska grows, particularly in the Railbelt (the area lying between Fairbanks and Anchorage along the Alaska Railroad/George Parks Highway corridor), we can expect the nature of the area along the east side of Denali to become more settled and less rural.

The Resource Management Plan (Denali National Park and Preserve 1998) notes that the most significant effects on Denali from industrialization result from activities in areas far away from Denali. Air pollution monitoring at Denali since the early 1980s has documented the occurrence of low levels of Arctic Haze. Arctic Haze is a winter pollution phenomenon. Pollutants, most likely from Eurasian sources, become trapped in the stable winter air mass that hangs over the arctic and extends down into North America and Eurasia, creating Arctic Haze (Shaw 1995). Recent monitoring also has suggested pulses of contaminants that apparently are transported directly from Asia (C. Cahill, University of Alaska Fairbanks, pers. commun.).

Another aspect of global industrialization that will affect the Denali Ecosystem is global warming due to increased amount of greenhouse gases in the atmosphere. As discussed earlier, warming has already been observed at Denali (Juday 2000) and could have many effects, such as melting of permafrost which could cause large changes in vegetation, landforms, and fire regime, with cascading effects on aquatic systems and wildlife.

In addition, industrialization elsewhere on the globe could adversely impact birds of Denali. Most of the bird species that breed in Denali are migrants who spend most of the year elsewhere in North, Central or South America, at sea in the North Pacific, or on South Pacific islands. One species, the Arctic Warbler (*Phylloscopus borealis*), winters in Southeast Asia, and another, the Northern Wheatear (*Oenanthe oenanthe*), winters in central Africa. While global industrialization may not affect the breeding habitat of these species in Denali, the same may not be true of their migratory paths or wintering habitats. Adverse impacts could include reduced overwinter survivorship and increased contaminant levels.

Similarly, global industrialization could affect the anadromous fish of Denali. Salmon that spawn and rear young in the streams and rivers of Denali spend most of their lives at sea. Changes in the oceanic environment due to global industrialization could affect the number of salmon returning to Denali.

Settlement

Settlement refers to the construction and occupation of permanent human structures. Human settlement affects areas both within the park and along the borders of the park. Within the park, at the eastern and western ends of the Park Road, settlement associated with park operations has intensified as the number of park visitors has grown. With increasing demand for public access, the number of businesses on private inholdings in Kantishna offering accommodations for park visitors also has increased. Continued rapid growth in human population within the Railbelt causes concern about settlement impacts along the eastern, southern and northeastern borders of the park.

Access

As our consideration of past resource preservation concerns suggests, concerns about public access are among the most significant for Denali park. Three types of access change could occur:

1. A new primary access corridor that would increase the level of disturbance within the core park. Park managers consider this to be the most significant change. Repeated proposals to extend the Stampede Trail as a northern access to the park indicate a high potential for this kind of access change.

2. Increased density of access corridors (primarily foot trails) off the Park Road and other access nodes within the park.

3. Proliferation of access corridors from existing and emerging growth centers on the park perimeter. These growth centers currently include the Stampede area near Healy, the McKinley Village area near park headquarters, and Cantwell. The completion of a visitor center in the Tokositna region would open up areas on the south side of the park.

Increasing both motorized and non-motorized access can significantly alter Denali. Non-motorized uses such as hiking, climbing, rafting, kayaking, canoeing, biking and dog mushing are focused in a few areas of the park, leaving large areas unaffected. Recent increases in motorized uses, such as snow machines and aircraft (for flightseeing), have been observed.

Roads and trails can change the land physically. The presence of people and vehicles on these roads and trails can be disturbing to wildlife. Impacts from access also can include:

- habitat loss and fragmentation,
- creation of edge effects,
- impediment to movement corridors or disturbance of normal activity patterns of wildlife,
- changes in hydrologic regimes,
- introduction of exotic plants,
- introduction of contaminants,
- air quality degradation, and,
- phenomena such as fugitive dust.

Access involves multiple types of impacts, yet the park must provide access for park visitors. This basic conundrum makes the access issue one of the most complex and important of the resource preservation concerns facing park managers.

Animal Harvest

As shown in the Denali Food Web (see Figure 7), humans harvest wildlife species inhabiting Denali. Sport hunting and trapping of wildlife is provided for in the preserve, and subsistence hunting and trapping are allowed in the preserve and new park. Fishing is allowed throughout the park. While current levels of harvest of Denali fish and wildlife are believed to be quite low, increased settlement in the Railbelt is expected to increase demand for consumptive uses of wildlife in Denali.

Plant Harvest

Firewood and house-log gathering along trap lines and adjacent to subsistence communities is allowed within the park. Berry picking also occurs. The current levels of plant harvest are believed to be low and localized near communities such as Cantwell. As for Animal Harvest, increased settlement in the Railbelt is expected to increase demand for consumptive uses of plants.

Mineral Extraction

Annual maintenance of the park road requires huge amounts of gravel, much of which comes from gravel mining of glacial river beds within the park. Thus, a main concern about mineral extraction as a potential source of adverse impact is related to an administrative use of park resources.

Mineral extraction on lands adjacent to the park is also possible. The Usibelli Coal Mine, in the Healy area, provides some indication of the value of the region for mining. The area at the eastern end of the Stampede Trail known as the "Wolf Townships" is open to mineral entry. Coal deposits are present in the Otto Lake area, also in the Stampede region, and the State of Alaska could promote development of these deposits. Areas around the park also have been explored for oil and gas, and some regions offered in state oil and gas lease sales. Extensive placer mining also has occurred in the Cache Creek area on the southern border of the park. Thus, while the current level of mineral extraction around Denali is low (except for Usibelli Coal Mine), the area has a recognized potential that could become attractive depending on economic conditions and regional growth.

Placer and lode mining in the Kantishna Hills region of the park early in the twentieth century has adversely affected streams, their riparian zones, and some uplands. Restoration of these mined areas is another park preservation concern that relates to mineral extraction.

Relationships Among the Concerns and Their Relative Importance

The potential sources of significant adverse impact to Denali relate, ultimately, to human population growth and associated demands. These concerns are not independent of one another. In Figure 8, we present a conceptual model of the potential sources of adverse impact and how they relate.

Human population growth and resulting industrialization drives all the concerns facing Denali. Global growth is the driver for the main sources of long distance air pollution, for global warming and for impacts to migratory birds and fish. Human population growth will increase settlement in the Railbelt, leading to local and regional industrialization and additional, closer, sources of air pollution. Increased settlement also will increase the number of nodes of access to the park, especially along the south and east sides. Increased human population also will increase demand for new access to the park and for increased number of facilities (settlement) within the park. Increased settlement along the borders also increases demand for both plant and animal harvest, which will be facilitated by increased access. Demand for increased access could result in a new road, which could increase gravel mining within the park.

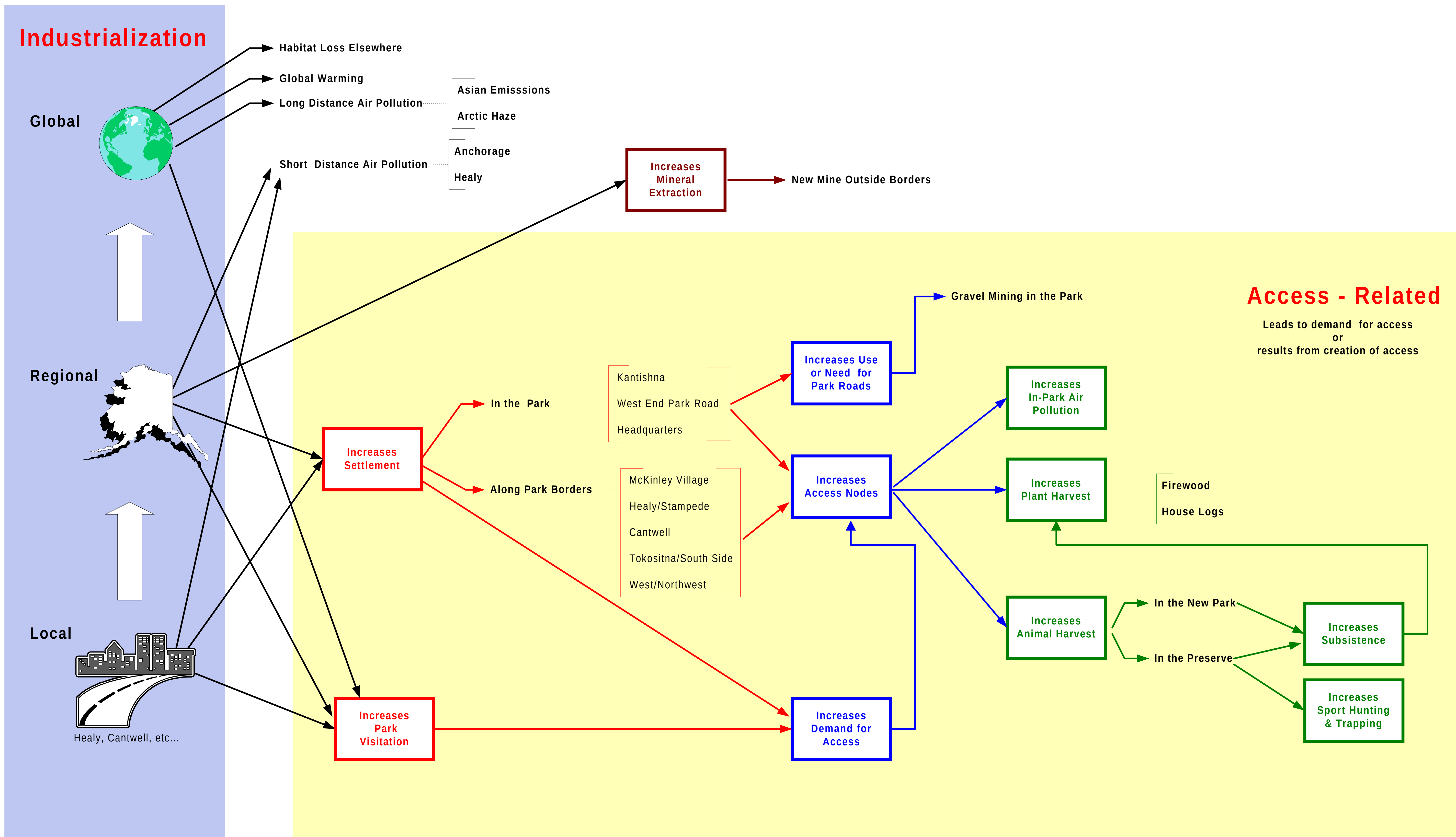
This analysis points to <u>access</u> as the central issue that ties together the issues of local and regional industrialization, settlement, harvest and mining. The issues related to global industrialization—air pollution, global warming and impacts to migratory birds and fish—represent a second suite of issues. To strategically deploy monitoring effort, a sense of the relative importance or level of concern the park has about these issues is needed.

The issues that lead to increased pressure for access or result from increased access have the highest level of concern because of their potential to change the undisturbed and unfragmented nature of the Denali Ecosystem. The issues of settlement, plant and animal harvest, and mining are inextricably tied to access and should be considered together. Access issues also are the types of issues that park decisions have a high probability to influence, by careful choices in siting of access routes and nodes and in management of human activity. The park can also have important influences on decisions related to animal harvest, plant harvest and mining within the park. Because of their potential to significantly impact the Denali Ecosystem, and because park decisions can reasonably be expected to prevent or reduce those impacts, the suite of issues related to access rank highest in our listing of resource preservation concerns.

Next in importance to park management are concerns that stem from global industrialization. Pristine air quality is a key value of Denali, a Class I park under the federal Clean Air Act. The issue of air pollution is therefore important, and the documented occurrence of episodes of Arctic Haze and emissions from Asia indicate that the park needs to be vigilant. Global warming, also related to global industrialization, is a concern because of the high potential for warming to change the Denali Ecosystem. However, park management will not be in a position to take action that could change that trajectory. In this case, the main role of park monitoring will be to understand the trajectory of change related to warming and the implications for park resources. A similar strategy applies to how the park should view protection of migratory birds and fish that may encounter increased mortality, pollution or habitat loss as a consequence of global industrialization when they are not at Denali. Monitoring these species within the park may provide early warning of problems that are occurring elsewhere.

We will revisit this analysis of resource preservation concerns in Chapter 8. In Chapter 8, we discuss strategies for ensuring that monitoring data will provide information to park managers so that significant adverse effects from access-related issues and global industrialization can be prevented or minimized.

Figure 8: Relationships Among Potential Sources of Significant Adverse Impacts to Denali National Park & Preserve



Part II: Design of the Denali LTEM Program

Chapter 6
The Goal and Two Objectives of the Denali LTEM Program

In the Introduction, we briefly presented the goal and objectives of the Denali LTEM program. We now return to this topic and lay out more fully the rationale for the goal and objectives. In implementation of the program, we will need to return time and again to this statement of purpose to ensure that the monitoring program is on track. Every aspect of the program, from the attributes we monitor, to the methods and sampling designs used, to the reporting mechanisms, depends on the goal. The goal must be stated clearly and explicitly so that it can be fully understood and agreed upon by everyone involved in the program, now and in the future. To get this buy-in—mandatory for the program to persist for decades and centuries—the goal must be commonly thought to make sense and be logically linked to purposes of the National Park Service, and of Denali National Park and Preserve.

Goal of the Denali LTEM Program

The goal and objectives of the Denali LTEM program are set within the overall mission of the National Park Service and of Denali National Park and Preserve. That is, our goal follows logically from these higher statements of mission and purpose at the national and park levels.

The mission of the National Park Service:

> *. . . is to preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations* (National Park Service 1997).

The mission of Denali National Park and Preserve is:

> *. . . to ensure the protection of wildlife, natural and cultural resources, and aesthetic and wilderness values along with the use and enjoyment of the park by present and future generations. It is the park's mission that visitors understand and appreciate the significance of natural systems. Recognizing the unique development*

> *and character of Alaska, we are also responsible for sustaining subsistence lifestyles and a setting conducive to scientific investigation* (Denali National Park and Preserve 1997b)

Thus, from the national and park-specific purposes, it is clear that we must preserve and protect the ecosystem that comprises the park, for current and future generations. For Denali, the mission is to understand the ecosystem, so that the ecosystem can be preserved and so that this understanding can be communicated to visitors. As a park with ANILCA additions, Denali also recognizes its responsibility to sustain human uses that are part of a subsistence way of life. Scientific investigation becomes the key to understand the ecosystem. This vital understanding forms the foundation for park policies to protect and preserve the park—fundamental policies that the park will communicate to visitors.

From these statements of broad purpose, we find the following to have great importance:

- protection and preservation of a natural ecosystem;
- understanding the ecosystem;
- communicating ecosystem understanding to the lay person;
- recognizing humans living a subsistence way of life as part of the ecosystem.

All of these relate ultimately to protecting, preserving and understanding the ecosystem.

We therefore set the goal for the Denali LTEM Program as follows:

> **Goal**: Help park managers protect the resources of Denali by providing the ecological context for resource preservation decisions.

We have chosen a single goal so the purpose is clear. Having multiple goals can be confusing. With multiple goals it is possible to be selective about which goal receives the most attention. Multiple goals also make it difficult to determine if you are achieving your goals. We focus our goal on providing scientific information to support management decision-making because it is these decisions that will protect and preserve the park, our ultimate purpose. Thus, the Denali LTEM program will singlemindedly pursue the improvement of the ecological information base to support decision-making that leads to protection and preservation of the Denali Ecosystem[5].

How Do We Meet This Goal?

To meet this goal of protection and preservation of the park via improved information to support decision-making, we believe two lines of effort are required. With two lines of effort, we will face some challenges in achieving the correct balance between them, but both are necessary. We describe these lines of effort as objectives. One has a *management focus* and the other has an *ecological focus*. The two are related in that the *management focus* objective depends on the *ecological focus* objective.

Management Focus Objective

To provide timely information to decision makers to determine if the ecological status and trends require a change in management.

This objective requires the monitoring program to provide early warning of problems that changes in management action can correct or avoid. This objective gets directly at the program goal by feeding information to park management. The "early warning" feature of this objective is especially important because of the park's duty to protect and preserve. The overall strategy of park protection and preservation ideally is based on avoiding problems, rather than correcting problems after-the-fact. The monitoring program can contribute to this "problem-avoidance" strategy by focusing on sensitive indicators that give advance notice of adverse changes that could be corrected, or preferably avoided, by management action.

5. Earlier in its history, the Denali LTEM program had three goals. Each of the goals was worthwhile and worth achieving, but taken together, almost any monitoring could be undertaken and justified as fitting one of the goals. Without knowing which of the three goals was truly the most important, there was no rational basis for prioritizing monitoring effort. Financial and human resources available for monitoring will always be limited, so we need to have a basis for prioritizing effort. We hope to avoid this difficulty by focusing on a single goal.

Ecological Focus Objective

To improve understanding of the Denali Ecosystem.

The *ecological focus* objective asks the monitoring program to provide information that helps us understand the Denali Ecosystem. Our rationale for this objective is that ecosystem understanding is critical to protection and preservation of that ecosystem. One cannot do a good job of protecting an ecosystem one does not understand. Ecosystems are complex and must be observed over long periods to understand how they function. The boundaries of Denali encompass and protect an intact, naturally regulated and functioning subarctic ecosystem that is currently unfragmented and not greatly affected by border encroachments: This is key. The ability of the park to protect and preserve that ecosystem will depend on the park's credibility when it comes to explaining how that ecosystem works and why management actions and policies, which may not be easily understood or accepted by the public, are needed. The ability of the park to be credible in its defense of the park ecosystem will depend on its knowledge and on its ability to convey that knowledge in a way that can be understood by the public.

The *ecological focus* objective provides the foundation for the *management focus* objective. We need ecosystem understanding to determine how to apportion our monitoring effort to achieve early warnings of danger to the park.

Having laid out the goal and objectives of the Denali LTEM program, and the rational basis for them, we turn now to the specifics of how we will achieve them. We first describe how the monitoring program will be organized, then discuss strategies for linking monitoring to the most important resource preservation issues. We then discuss transition from the original design to the design presented here.

Chapter 7
Organizing Monitoring Effort

We now describe how we will meet the goal of the Denali LTEM program. We begin by describing how the monitoring program will be organized into four building blocks—termed components—based on our conceptual ecosystem model. Our rationale for this approach is that an ecological monitoring program must include both physical science and biological science components because an ecosystem is comprised of the interacting parts of the physical and biological world. If the program includes one but not the other, we will not be able to build our ecological understanding.

Trial and error led to this approach. We tried to prioritize potential monitoring projects using various ecological criteria, such as "importance in the food web" and "importance to a natural process." We found it difficult to rate projects objectively.[6] How high we rated a particular project on these ecological criteria was biased by our individual expertise. Moreover, we did not feel that our knowledge of the Denali Ecosystem allowed us to definitively state that one part of the ecosystem had more importance than another, at least in an ecological sense (e.g., are wolves more important than fungi? To be whole, the ecosystem needs both.) Our efforts at allocating monitoring effort in this way were unsuccessful and therefore abandoned.

We concluded that creating an ecologically balanced monitoring program requires inclusion of both physical and biological components. Further prioritization of monitoring will best occur within these components.[7] Then, even with reductions in resources available for monitoring, a fundamental ecological balance will remain in place within the monitoring program. This method of organization supports our goal of protecting and understanding the ecosystem.

Based on our ecosystem model, we will divide the program into four major monitoring components, one to cover the physical science components, and three to cover biological science components. Each component represents an indispensable building block in the program. The monitoring components will include:

- physical environment,
- aquatic systems,

6. In contrast, we found it relatively easy to rate potential monitoring projects using "relevance to management" criteria.
7. Humans are part of the "biological" components, but we have not fully developed our strategy for incorporating social factors into the monitoring program design.

- vegetation, and
- wildlife.

With some long-term monitoring effort in each of these components, monitoring will be balanced among the primary components of the Denali Ecosystem.

Monitoring efforts within each component will be allocated and led by the people on Denali's staff generally responsible for those subject areas. We refer to these people as the Park Leads for LTEM. The Park Leads will ensure that all monitoring effort within the component is consistent with the goal and objectives of the Denali LTEM program. (Specific responsibilities of Park Leads are discussed in more detail in Chapter 10 on Program Management.) Below, we will describe further what is included in each component.

Physical Environment

The most important abiotic factors in the Denali Ecosystem will be monitored via the *Physical Environment* component. Within this component we include meteorology, snow cover, air quality, soils, hydrology, and glaciers. We recognize that this component includes elements that are not strictly abiotic (nonliving). Soil results from both biotic and abiotic factors. Vegetation, in boreal systems, can influence the weather (Dissing and Verbyla 1999). Most forms of air pollution result from biotic (human) activity. Under current staffing levels, Denali has a physical scientist and an air quality manager who will lead monitoring in the *Physical Environment* component.

Aquatic Systems

In the *Aquatic systems* component, we bring together elements from the other three monitoring components: water quality, hydrology and glaciers from *Physical Environment*, riparian vegetation from *Vegetation*, and aquatic animals, as identified in the *Grayling Web*, from *Wildlife*. We purposely choose to combine the important elements of aquatic systems into a separate component (rather than including them in the other components) to facilitate integration. Monitoring in the *Aquatic Systems* component will be led by the Park's hydraulic engineer.[8]

8. Ideally, an aquatic ecologist would lead monitoring in this component. Currently, Denali park does not have an aquatic ecologist. Responsibility for directing monitoring of *Aquatic Systems* will be assigned to the hydraulic engineer.

Vegetation

Vegetation and factors that affect vegetation or are typically part of vegetation sampling will be monitored via the *Vegetation* component. These factors include a suite of elements related to fire, including the occurrence and location of fires, duff layer, and downed woody debris. The principal decomposition processes of terrestrial systems also would be included, as appropriate, in the *Vegetation* component. The park's plant ecologist, working closely with the park's fire management officer, will lead monitoring of the *Vegetation* component.

Wildlife

Within the *Wildlife* component, monitoring effort will take into account the interaction webs identified in the Denali Food Web. Thus, we choose an ecological division of effort, rather than a taxonomic one. Under current staffing levels, Denali has an Ornithologist and a Wildlife Biologist who share responsibility for wildlife monitoring and research. Under this organization scheme, monitoring effort for wildlife will be divided among the six interaction webs that include terrestrial wildlife: *wolf web*, *bear web*, *hare web*, *vole web*, *red squirrel web,* and *merlin web*. Responsibility for monitoring in each of the webs will be assigned to one of the biologists, and the biologists will share responsibility for allocating effort among the interaction webs.

At this juncture, we must make note that including consideration of all species of wildlife within the LTEM program is a new and important feature of this Conceptual Design. Charismatic megafauna (i.e., wolves, caribou, moose, sheep, bears, golden eagles) were not included in the original program design (Van Horn et al. 1992). The unstated assumption for this was that money would probably always be available from other sources to fund research on these high visibility species. Thus, the money for the LTEM program would be devoted to looking at the aspects of the ecosystem, which although important, might not otherwise ever be examined. While this approach allowed work to begin on neglected aspects of the ecosystem, it also allowed the two monitoring efforts (megafauna and everything else) to follow separate paths, making it difficult to develop a unified picture of the Denali Ecosystem or how it might be changing. Although funding for megafauna monitoring has recently been included within the Denali LTEM program, from both park base and national program sources, the conceptual basis for including the megafauna in the monitoring program has not been explicitly identified until now. We now take a more holistic approach to monitoring in the *Wildlife* component, which is necessary for the LTEM program to meet its overall goal and objectives.

Chapter 8
Linking Monitoring Components to Resource Preservation Concerns

The Denali LTEM program will provide information to support decision making by park management on resource preservation concerns. For this to happen, design of the program must specifically consider the most likely concerns. Such resource preservation concerns, and the importance we give them, will affect the attributes selected for monitoring and the sampling design. Hence, the concerns must be stated explicitly during the formulation stage so appropriate strategies can be devised.

In Chapter 5, we described how the potential sources of significant adverse impact to Denali park fall into two groups: those related to access and those stemming from global industrialization. In the previous chapter, we described how monitoring effort is allocated among ecological components: *physical environment*, *vegetation*, *aquatic systems* and *wildlife*. In this chapter, we outline strategies for linking monitoring components to the most important resource preservation concerns. Our purpose is to provide general guidance to Park Leads about how best to target monitoring effort within their specific component to address the identified concerns. Common to all strategies is the need for additional conceptual models to focus monitoring effort.

Access-related Concerns

Because access-related issues have the highest potential to impact park resources, and because park managers can directly influence how the park avoids or mitigates impacts, strategies for each monitoring component need to consider whether long-term data to help the park address access concerns can be generated. Further development of our conceptual model of possible impacts from access-related concerns (and how to avoid them) is required.

Although all the components are involved in some way, the *Wildlife* component has a particularly important role to play. One of Denali's primary assets is its large unfragmented area with relatively little settlement around its borders. This provides the setting for large mammals that roam widely or have large home ranges, to move and live largely free of human influence. All organisms in Denali benefit by living within the "umbrella" of the large home ranges of large mammals, whose use areas are protected via national park status. Understanding the movement patterns and ecology of species that require large areas could be instrumental to pro-active decisions relating to access.

For example, caribou monitoring data likely will be important to prevent access-related problems. Caribou (part of the *wolf web*) typically occupy different areas during summer and winter and during calving. Based on observations during the past century, the range of the Denali Caribou Herd shifts. The population is currently low (around 1,000 caribou), but has been much higher in the past (> 20,000 caribou) and the herd could increase in the future, likely expanding or changing the areas used. Thus, to address access-related concerns, we need to understand how caribou use patterns change over long periods. Caribou figured prominently in creation of the park and in the ANILCA additions, and long-term data on the distribution and status of the Denali Caribou Herd likely will figure prominently in any discussion of new access.

Information about Denali grizzly and black bear populations will also figure prominently in development of strategies to avoid access-related impacts. Because bears are attracted to human food, bears are probably at the most risk from increased settlement within the park, increased access corridors (which would increase encounters between visitors and bears), and increased settlement along the park borders. Settlement along park borders is a concern because the number of bears shot in defense of life and property[9] will undoubtedly increase. The existing bear-human interaction monitoring system works well to detect and correct problems once they have occurred. The long-term ecological monitoring program will need to generate information about bears to avoid such problems. For example, knowing the areas that bears use and traverse would allow such areas to be completely avoided during development or protected by buffers.

We have discussed caribou and bears to suggest their general importance to address access-related concerns. Monitoring other wildlife species will also be important. Further conceptual

9. Taking a bear “in defense of life and property” is allowed by Alaska law, hence the origin of this phrase.

modeling of potential impacts, focusing on prevention rather than mitigation of those impacts, will determine just how important.

While the *Wildlife* component of the monitoring program will play a key role in addressing access-related concerns, the *Vegetation* component also will be involved. Access corridors provide avenues for introduction of exotic plant species, and plant harvest could increase to the point where it affects park resources. Another part of the *Vegetation* component that intersects access-related concerns is fire, specifically the need for fire suppression in settlement areas. Fire and vegetation monitoring could suggest what areas are most at risk from fires and therefore where to avoid development, if possible.

Global Industrialization

Air Pollution

Under the Clean Air Act, park managers may mitigate air pollution that originates outside the park's boundaries, but solid data on air quality are required to demonstrate that pollution could occur or has occurred. Air pollution could increase from global, regional, and local industrialization, and increased use of motorized vehicles within the park. The low detection limits of some pollutants may also provide some early warning of incipient contamination problems. Degradation of air quality can cause shifts in lichen and other plant communities, which could affect animal species that depend on lichens and other affected plants for food. Further development of the vegetation monitoring component should consider the probability of detecting responses of vegetation to air pollution.

Global Warming

Long-term ecological monitoring is ideal to document ecosystem changes due to global warming. More useful to park managers, however, will be prediction of changes—especially cascading effects. Each of the monitoring program components has the potential to be affected by global warming, and further development of monitoring strategies for dealing with the global warming issue should follow a modeling approach. The conceptual ecosystem model for Denali, in conjunction with the considerable process-related research now underway, should be used to develop logical outcomes. These outcomes would then be used to select the most appropriate attributes for monitoring. Such attributes will likely be spread out among the four monitoring components. Until the effects modeling is done, we cannot determine how much effort should be placed into monitoring related to global warming, or how that effort should be allocated.

Migratory Birds and Fish

The migratory birds of Denali fall into the *grayling*, *hare*, *vole,* and *merlin* interaction webs. The migrants fall into different risk classes, depending on the location of their migratory routes, wintering grounds, and how subject to human interactions (e.g., hunting) they are when they are not in Denali. In addition, some species have more importance from a rarity or special status point of view, perhaps warranting focused monitoring. A holistic approach that considers the risk and significance of all migratory birds should be used to guide further development of long-term monitoring of bird populations in the park.

The migratory fish of Denali—salmon—are in the *grayling* interaction web. Little information is currently available about their occurrence, distribution, abundance or ecological significance within the Denali Ecosystem. Further development of monitoring effort within the *Aquatic Systems* component will need to consider potential impacts on salmon from forces outside Denali.

This discussion of strategies to link monitoring components to resource preservation concerns is not, and is not meant to be, definitive. Rather, our purpose is to suggest the most obvious links. The most important point is that the design of monitoring for each ecological component must address the identified resource preservation concerns. They must be addressed in a way that demonstrates how the monitoring data will help the park make decisions that preserve park natural resources.

Chapter 9
Transition to the New Conceptual Design

The design of the Denali LTEM program will not be finished until the specific designs for each monitoring component have been revised to align with the program goal and objectives set in this document. Because monitoring activities have been ongoing at Denali since 1992, we recognize that this “design completion” step will be more of a “design adjustment.” The main benefit that will accrue is that all parts of the program will be ultimately aligned with the program goal. In addition, all parts of the program will now be held to the same standard of improving the scientific information base for decisions that protect the Denali Ecosystem.

Our approach is to use the monitoring program development process (see Figure 4) to evaluate ongoing monitoring effort in each component in light of the revised goal and objectives. Teams composed of the Park Leads and appropriate technical experts, including a statistician, are identifying necessary adjustments. Once the adjustments for each monitoring component have been recommended, we will consider them as a whole. In this evaluation, we will:

- determine if similar sampling designs can be used among the monitoring components,
- ensure that each monitoring component has considered data needs of the other components and that appropriate ecological links have been made,
- ensure that the collective program meets the overall program goal and objectives.

In this regard, we recognize that each monitoring component will contribute different types of information toward the *management focus* and *ecological focus* objectives. Thus, an important part of this evaluation will be to consider if the overall program covers all the resource preservation concerns or if an important concern has been neglected or cannot be addressed. Similarly, for the *ecological focus* objective, we must consider if the program is ecologically balanced.

As an example of how this transition process is working, we now briefly consider the status of monitoring design work for the *vegetation* component. Our recent work on vegetation monitoring demonstrates how we are changing the program to rectify the limitations identified by the 1995 review team.

Transition Example: Vegetation

Under the original design, vegetation monitoring began in 1992 on several permanent plots within the Rock Creek drainage. In 1998, an evaluation of the vegetation monitoring data spurred a reconsideration of objectives for vegetation monitoring (Roland 1999). In terms of the program development process (Figure 4), we had made it all the way to the final step in implementation where we ask: Does monitoring meet the objectives? Our answer "not exactly" sent us back to the design stage. We assembled a team to reconsider vegetation monitoring objectives and to develop and test appropriate methods. The team includes: the Denali Plant Ecologist, an ecologist from the NPS Alaska Support Office, the Denali LTEM Program Manager, a vegetation ecologist from the University of Alaska Fairbanks (supported by USGS funds), a statistician (supported by USGS funds) and the USGS project leader assigned to the Denali LTEM program.

For each vegetation monitoring objective, the team has developed a thorough rationale statement. These statements describe links to the overall program goal and objectives, identify specific attributes for measurement, and describe foreseeable applications of the data to park management questions. The team has divided the objectives into two categories based on their spatial scale: "landscape-scale" or extensive monitoring objectives, and "intensive-scale" monitoring objectives. A key difference between these two categories relates to the area of inference associated with the objectives. For the landscape-scale objectives, we seek to make direct inferences about changes in broad-scale patterns on the landscape. With the intensive-scale objectives, we intend to measure attributes that are too costly or complicated to monitor at the spatial scale of the park. The intensive-scale objectives also provide a way to incorporate existing long-term studies of Denali vegetation into the LTEM program.

Based on the newly defined landscape-scale objectives, we are testing a sampling methodology based roughly on the U.S. Forest Service's Forest Health Monitoring (FHM) program.

Modifications appropriate to the specific monitoring objectives of Denali are being incorporated.[10] The ideal sampling design is a systematic grid (with a random starting point), and we are currently modeling how the grid would work to determine its feasibility, given financial and logistical constraints. Testing of the methods for addressing the extensive-scale objectives will occur in the summer of 2000, setting the stage for writing of the protocol and development of data management and analysis routines in 2001.

10. In the process of redefining the objectives for vegetation monitoring at Denali, the team investigated the Forest Health Monitoring (FHM) program to determine its possible application at Denali. Many of the features of the FHM program are worthy of adopting for use in Denali, however, the objectives of the two programs differ. Thus, some aspects of FHM are not of interest to Denali, and some attributes of particular interest to Denali are not included in the FHM methods. In addition, the spatial and temporal scales of interest differ between the two programs.

Part III: Programmatic Feature

Chapter 10
Program Management

An important, but often neglected, step in developing monitoring programs involves establishing a core staff and funding. Having this step in place will help make the program more cost-effective and responsive (Mulder et. al. 1999).

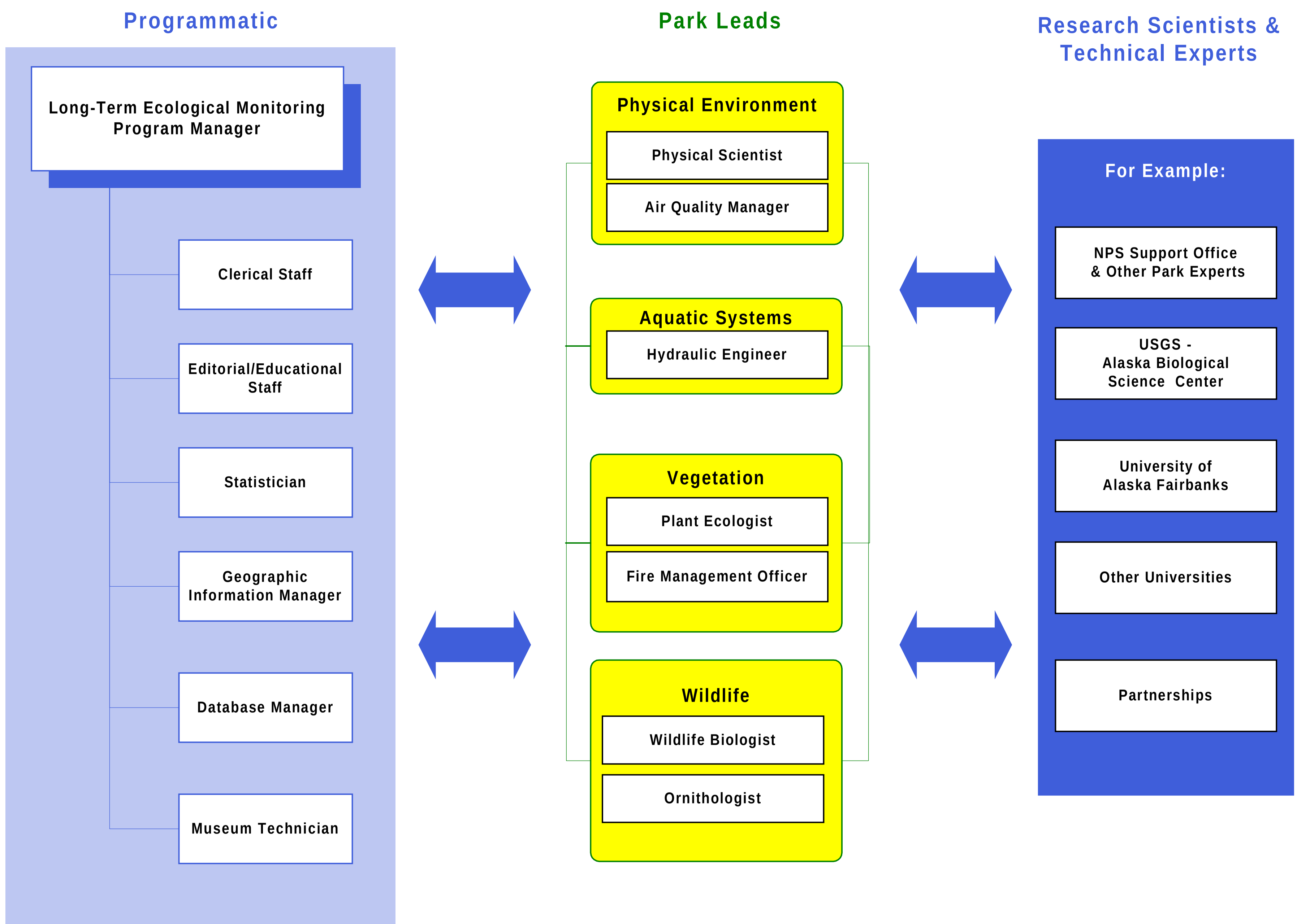
Who is Responsible for Managing the Program?

The Denali LTEM program functions as an integral part of the Resource Management program, which is part of the Division of Research and Resource Management. Staff within the division will have responsibility to carry out the Denali LTEM duties, in addition to their other duties. The LTEM program is organized into two levels (see Figure 9): programmatic level and project level.

The programmatic level consists of a program manager, statistician, database manager, geographic information system manager, museum technician, science/education assistant, and clerical staff. The programmatic team is the focal point for the administrative duties of the Park's extensive multi-disciplinary monitoring program. This means ensuring consistency and enhancing understanding of key monitoring concepts. Furthermore, the programmatic team provides oversight on developing monitoring strategies, developing protocols, supervising field activities, producing reports, assisting science and educational programs, and coordinating activities of Park Leads and cooperators in all aspects of the program.

At the project level (see Figure 9), key staff consists of the Park Leads and any temporary employees hired to work for the LTEM program, and collaborating scientists and individuals from other agencies or institutions. The project level teams have the expertise needed to take the lead in monitoring specific

Figure 9: Denali LTEM Program - Park Staff and Cooperators



components. Areas of expertise include not only understanding physical, biological, and social dynamics of the ecosystem but also knowledge of applied statistics, sampling designs, and analytical tools (e.g., Geographic Information System). The blending of the programmatic and project level teams is essential to the long-term success of the program.

Role of the Park Leads

Park Leads have the significant responsibility for implementation at the project-level of the Denali LTEM program. Park Leads are responsible for:

- allocating effort within the monitoring component;
- determining and prioritizing specific, measurable objectives for long-term monitoring within the component;
- carrying out or supervising the monitoring work;
- integrating and synthesizing monitoring findings with data coming in from other efforts, such as inventory, *adaptive management monitoring*, and research, at Denali and elsewhere;
- coordinating with the other components and integrating findings among components; and,
- communicating findings.

The Park Leads are indispensable to the successful execution of the LTEM program. Park Leads know and recognize best the most important elements of their monitoring component. They are in the best position to set up the monitoring in a way that provides a foundation for the inventory, research, and *adaptive management monitoring* efforts that the park also needs in its overall resource preservation program. Because of their subject area expertise and their involvement in these other efforts, the Park Leads also are the best people to integrate findings from the long-term monitoring effort with findings from these other efforts.

While allocating monitoring effort among the four components ensures ecological balance, we must guard against the possibility that work in the components starts to follow separate and possibly diverging tracks. Each Park Lead must be responsible for coordinating and communicating with other Park Leads to integrate monitoring findings. The LTEM Program Manager also has a significant role in this respect. The Park Leads, as the main integrators of information, also have significant responsibility for communicating findings.

Financial Management

Funding for the Denali LTEM program primarily is derived from base funding from the park's resource management program and by annual funding increments from the national I&M program. Some funding from other sources is also received. At the park level, the Denali LTEM Program Manager is responsible for management of these funds to carry out the LTEM program. Allocation of the LTEM budget is made on an annual basis. A portion of the funding is allocated for support of programmatic level staff. The remainder is allocated to the Park Leads for operational activities.

Administrative Reporting

Our administrative reporting process begins with the linkages to the LTEM *Strategic Plan* document that builds upon the LTEM Conceptual Design (this document). The *Strategic Plan* includes the LTEM vision, goal, objectives, and long-term tasks. These tasks, scheduled to take approximately five years, are stated as desired outcomes that we intend to accomplish year by year.

The *Annual Work Plan and Budget* is the principal source of budgetary documentation and is prepared at the beginning of each fiscal year. It outlines the monitoring tasks, addresses planning and budgetary needs, timelines, staffing, and performance standards tied to each monitoring component. The LTEM Program Manager also identifies research proposals and other projects that may be important to improving the program. The work plan is signed by the Park Superintendent and submitted to the national I&M Program Manager.

Chapter 11
Information Management and Transfer

The primary functions of information management are to assist in collecting, organizing, validating, storing, and retrieving data and in preparing reports. An effective information management system is essential to any monitoring program but especially to one of this scope and complexity (Palmer and Mulder 1999). In this chapter, we address the topics of quality assurance and quality control, data management, and reporting. We also discuss collaboration because of its importance to information transfer.

Quality Assurance and Quality Control

The major purpose of any quality assurance/quality control effort is the production of data that are of a quality consistent with known levels of accuracy (the sum of random and systematic error) and precision (mutual agreement among replications). Quality assurance is the application of procedures that reduce sampling and analyzing errors for improved data precision. The quality assurance procedure begins with the initial data collection design, and is in place throughout data collection, analysis, integration, and storage (National Park Service 1992). Shampine (1988) notes that the potential problems faced by LTEM programs have been with data quality, consistency and comparability, and availability and accessibility. A quality assurance/quality control effort can effectively address these problems. Resolution of these problems will help the LTEM program meet management and ecological objectives. In addition, an effective quality assurance/quality control endeavor would expand the utility of the data to the entire scientific community. National Park Service (1992) defines six procedures that are routinely applied:

1. use of consistent collection and analytical methods over time;
2. use of equivalent monitoring equipment among different sites;

3. use of consistent formats in field and laboratory data reporting and structure of files;

4. use of procedures that maximize the capacity to integrate data sets with a minimum of manual data re-entry (GIS technologies);

5. maximum use of automated data handling techniques that ensure quick access to recently acquired data and ease of access to all data; and

6. use of existing and proven data collection protocols.

Quality control is the application of specific procedures in sampling and analysis to ensure that precision and accuracy of results is built into the monitoring effort. Precision is the degree to which repeated measurements of a quantity vary from one measurement to another. Accuracy is the degree to which measurements differ from a true value (Peterson et al. 1995). Three factors influence the precision and accuracy of the measurements: (1) the precision and accuracy of the measuring tools and instruments, (2) the abilities of the individuals using the tools, and (3) the care and attention with which the measurements are made under the variable conditions of day-to-day operations.

The quality control process begins with data collection. The justification for change in any specific steps employed in gathering data is driven principally by changes in precision and accuracy objectives (National Park Service 1992). Following the statistical analysis of data that document conditions that could improve sampling precision and accuracy, revised sampling procedures might be required. That is, evaluating the precision of a measurement and/or the accuracy of the data to adequately detect trends. Nevertheless, in no instance are new methods to be employed merely for convenience or on the suspicion that they may improve data precision and accuracy. Instead, new methods are to be considered only when it has been determined that there is a need for data with better precision and accuracy. At that point, change should be brought about by calibration of the “old” and “new” procedures (National Park Service 1992, McDonald et al. 1998, Beard et al. 1999).

A major factor in quality assurance and quality control is consistency in the use of procedures, a process best ensured by employment of qualified and committed personnel (National Park

Service 1992). When the monitoring effort includes both spatial and temporal data collected over a large landscape, as in the case of Denali, the quality of personnel can be a major factor in the level of quality assurance. There is no substitute for attention to detail--this comes only from personnel who are committed to the long-term goal and objectives of LTEM. Personnel can detect situations that appear to deviate from the norm through familiarity with the indicators they are observing and an understanding of analytical procedures. And, often their observations or suspicions are the keys in detecting the need for better procedures, or perhaps even in taking a new conceptual approach in data acquisition or research.

Data Management

A standardized, systematic approach to data management is an essential part of any monitoring program. The objectives of database management are to ensure that data are stored and transferred accurately, secured from loss or damage, and made available to decision makers in a timely and understandable manner (Peterson et al. 1995).

As noted previously, a database manager is working full-time for the LTEM program. During the next year, the database manager will set up a single database to house all of the different datasets of the various monitoring components. This relational database will provide the ability to analyze results from different projects or datasets within the same project, and make it easier for investigators to obtain data from other monitoring components to determine ecological relationships. The database also will aid researchers by having a multitude of datasets (currently residing on different workstations) stationed in a single area. The primary objectives of this integrated database are to provide better access to collected data and to assist data analysis.

An interface between the LTEM database and Denali's existing Geographic Information System (GIS) program[11] (e.g., ArcView)

11. The Alaska Support Office has organized existing spatial data sets for each Alaska park into an ArcView application that allows park staff with minimal GIS training to access and easily use the data. Developing the link between the "Denali Browser" and LTEM data is an important part of our strategy for disseminating program findings.

will be established to extract and analyze spatial data from the various datasets. This will increase the ability of researchers to overlay program data onto different mapping layers such as vegetation, topography, and streambeds. Eventually, the non-sensitive LTEM information represented in GIS layers may be linked to the park website for public distribution.

Annual Reporting of Monitoring Results

The LTEM Program is not complete unless the results are distributed in a usable form and archived for future reference (National Park Service 1992). The LTEM Program Manager must provide a forum and mechanism for collaboration, information-sharing, and linkages between people and resources that are internal and external to Denali. This interaction can only be assured by a formal reporting procedure that promotes continuity and documents LTEM program growth, change, and the integrity of data. In addition, all reports and non-sensitive data from the LTEM will eventually be made available on the program's web page.

At the conclusion of each field season, annual reports will be prepared by Park Leads for each monitoring program component. A *Denali LTEM Annual Report* will be prepared by the LTEM Program Manager to integrate the findings from the annual reports for each component. The *Denali LTEM Annual Report* documents the condition and status of the monitoring components, including ancillary quality assessment and quality control results and recommendations. The *Denali LTEM Annual Report* serves as a repository for monitoring observations, a vehicle for disseminating information locally, and a mechanism for documenting management recommendations, including changes in monitoring procedures. Review, analysis, and application of this report will include input from entire park staff, and will foster understanding of resource preservation concerns that are linked to the LTEM program.

From the technical and scientific information generated from the *Denali LTEM Annual Report*, the staff and cooperative partners will produce contributions to *National Annual LTEM Report.* The National Inventory & Monitoring Program provides guidelines that highlight the monitoring and status of natural resources in national parks.

In addition to these reporting efforts, the Denali LTEM program will hold its first annual meeting in the fall of 2000. The meeting will include LTEM contributed papers and a poster session with a follow-up business discussion. During the business session all aspects of the LTEM program will be discussed. For example, discussions may include field work and logistics (what is or is not working), funding, program development, and strategies to increase our involvement with the science/educational program. This will be an excellent opportunity to measure the success of the LTEM program and to maintain an open dialogue among scientists and managers.

Collaboration

Among many challenges facing the LTEM program, building strong relationships with a variety of individuals, groups, and agencies will prove paramount in the information transfer process. Those who are currently involved in the Denali LTEM Program include: national-level staff for both the NPS and USGS, staff at Denali National Park and Preserve and the USGS-Alaska Biological Science Center; Principal Investigators from academia, other institutions, and the NPS, who are developing various protocols; peer reviewers; and professionals and technicians who carry out monitoring activities. Our efforts are based on the following themes:

- To provide incentives for people to work together and to contribute to LTEM Program in meaningful and useful ways.
- To provide incentives to other agencies, governments, businesses, organizations, communities, and citizens to contribute to a sound ecologically based LTEM program.
- Expand the network of Cooperative Ecosystems Studies Units recently created in partnerships with the USGS and other Federal Agencies.
- Increase involvement with the continuing science and education programs.
- Increase involvement in NPS interpretive programs.
- Expand LTEM scientific research with grants, logistic support, and cooperative studies.
- Continue the LTEM web site to promote data management and improve understanding and visibility of the LTEM program.

Examples of our collaborative efforts:

- Denali participates in several national monitoring networks that are incorporated into the LTEM program, including the Air Quality Monitoring Network (NPS-Air Resources Division), Headquarters Weather Station (National Weather Service), Snow Survey Network (National Resource Conservation Service), and the Park Research and Intensive Monitoring of Ecosystems Network (PRIMENet).
- We have increased LTEM involvement with the continuing science and education programs at the University of Fairbanks and public schools in both Fairbanks and Healy.
- We have increased LTEM involvement in the Denali interpretive division by becoming an integral part of the visitors program (presentations and field trips).
- As previously noted, we are developing an integrated, standardized database for LTEM data, maps, and bibliographic information.
- We currently have a LTEM web page (www.absc.usgs.gov/research/Denali/home.asp) that has provided a convenient source of information for a variety of audiences.
- LTEM Park Leads and Principal Investigators have presented papers and posters at number of professional meetings.

Chapter 12
Key Features of Protocols

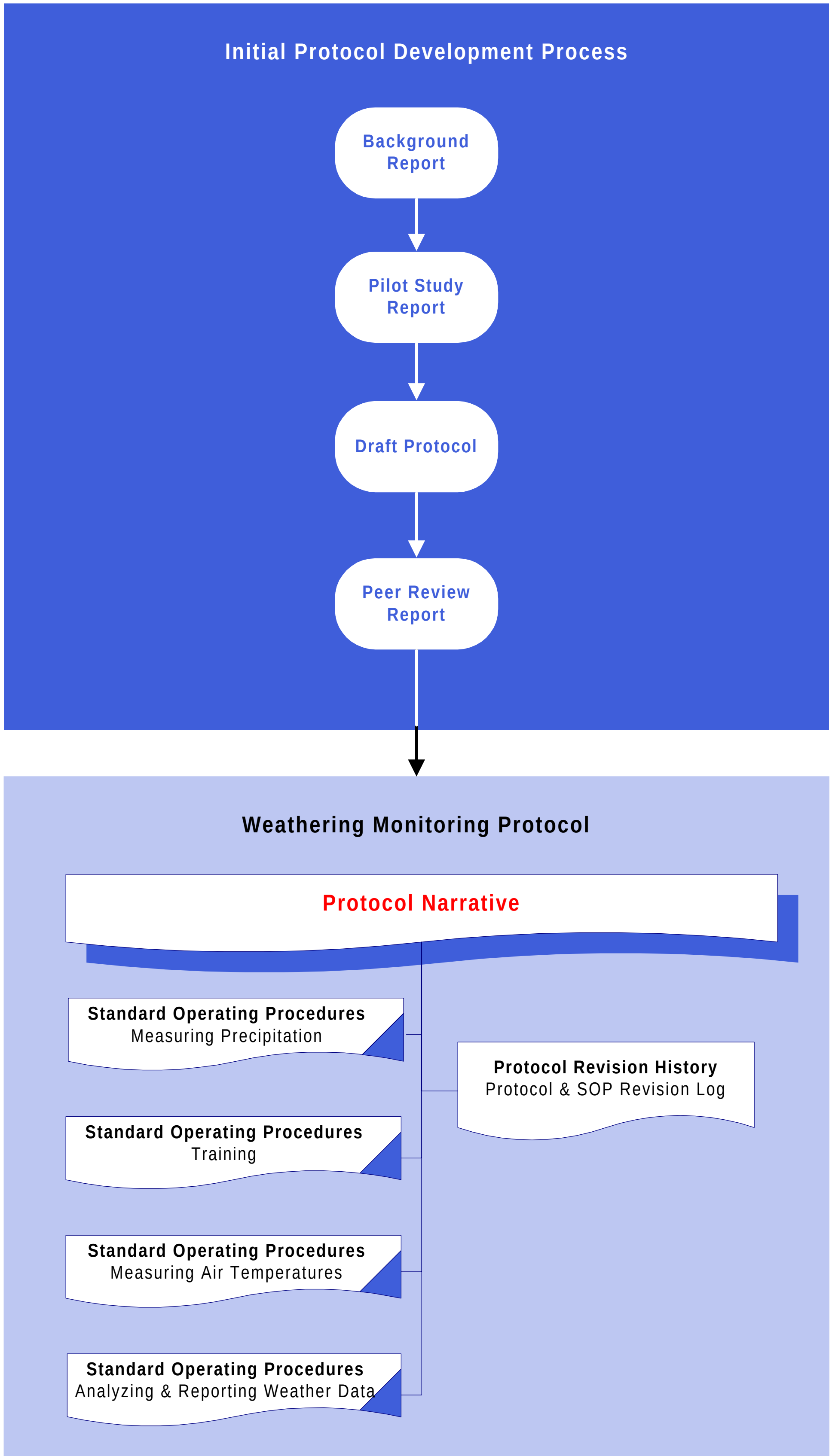
A written protocol for each component of the monitoring program will be required. The purpose of this section of the Conceptual Design is to provide general guidance about what information needs to be included in a protocol, who the protocols are written for, and the appropriate format. We begin by defining what a protocol is and why protocols are important in the context of long-term monitoring. We then provide an overview of the key features of the protocols to be written to implement the Denali LTEM program.[12] We conclude by discussing the pivotal role that protocols play in the monitoring program by pointing out their relationship to other aspects of the program. These relationships have important influences on how protocols are written.

What is a protocol?

According to the American Heritage dictionary, a protocol is "the plan for a medical or scientific experiment." For the purposes of the Denali LTEM program, we will rely on this definition: a protocol is a study plan. Protocols will consist of two distinct parts: (1) a narrative, and (2) Standard Operating Procedures (SOPs). The main body of the protocol will be the narrative, written to explain, in general terms, what will be done, and why. Attached to the narrative will be any number of Standard Operating Procedures (SOPs). SOPs are instructions written for the current and future people actually doing the work. Because SOPs are for use by the people actually doing the work, special formatting—to improve readability—is recommended (Wieringa et al. 1998). We define a protocol to include both the narrative description of the monitoring activities, and the SOPs (see Figure 10). The narrative provides the context for the procedures.

12. This overview will be augmented in the near future with separate, more detailed guidance and an example protocol.

Figure 10: Development and Parts of a Monitoring Protocol - An Example Using Weather Monitoring



Audiences for monitoring protocols include:

- current and future monitoring program managers,
- current and future peer reviewers,
- current and future Park Leads—the person who manages the monitoring work for a given component of the overall monitoring program,
- current and future technical staff—the people who actually carry out the work, and
- current and future scientists hoping to use the data collected by the monitoring program.

We choose to emphasize that the audience includes people in the future. The success of the monitoring program depends on our ability to communicate exactly what must be done so that measurements taken by different observers at different and widely separated points in time prove consistent and comparable.

Because the protocols are being written within the context of long-term ecological monitoring, the protocols need to be written with greater amounts of background information and greater attention to detail, than is the case for the typical research project (Geoghegan 1996). Moreover, the protocols need to be stored in a manner that keeps track of revisions, and allows the exact methods used in any given year to be easily reconstructed.

Why are protocols so important in long-term monitoring?

Long-term monitoring faces challenges not evident in the typical research project. Measurement error and consistency is a much greater concern. To be sure that any change detected is the result of an actual change, and that changes are not masked by inconsistent methods, one must be confident that the data were collected with known, repeatable and documented methods. The quality of the data must be known. The many subtleties in the collection, handling and analysis of data may affect its future use—these subtleties need to be documented to provide future data users with the information they need to evaluate data quality.

Sources of measurement inconsistency include:

1. changes in the technique of measurement, often due to improvements in technology,

2. changes in personnel (a given in any long-term monitoring program),

3. changes in what is being measured (e.g., dropping one attribute in favor of another),

4. changes in the location where measurements are taken (e.g., the National Weather Service station within the Denali park headquarters area has been moved several times in its approximately 75-year history, each move resulting in a recognizable change in the data), and

5. changes in the frequency and timing of measurement (Beard et al. 1999).

<u>Measurement errors are much easier and less costly to prevent, than to correct</u> (Geoghegan et al. 1990, Beard et al. 1999). The key to preventing such errors is to have a Quality Assurance/ Quality Control Plan (Shampine 1993). The heart of any such plan is a detailed statement of the methods to be used, and a documentation of the methods actually used (Geoghegan 1996).

What goes in the Narrative?

The narrative portion of the protocol provides contextual information and should be perceived as a clarifying document for both management and personnel conducting the program. The narrative should be written in a study plan format and should include:

- a statement of objectives, including explicit information on how the objectives relate to the overall LTEM program goal and objectives,
- a description of models used in the design stage to select attributes,
- a description of the sampling design and the rationale for its selection,
- general descriptions of the measurements to be taken (the details will be provided in the Standard Operating Procedures),
- data quality objectives and quality controls required to meet those objectives,
- a format for how data will be organized, documented, analyzed and reported,

- budget information and an indication of what measurements will be taken and what methods would be used under varying budget scenarios,
- the history of the protocol's development, and
- a list or flowchart referencing all the SOPs that are a part of the protocol.

Standard Operating Procedures

The narrative portion of the protocol will reference all the Standard Operating Procedures that have been written to carry out the work. An important part of the protocol development process will be in deciding how to break up the work into SOPs that make sense. Every protocol can be expected to include several SOPs. For example, a protocol for small mammal population monitoring might include SOPs for:

- field season preparations (what equipment needs to be gathered, supplies to purchase, etc.),
- field crew training,
- laying out the trapping grid at the beginning of the season,
- handling a small mammal once it has been captured,
- daily downloading of data from the recorder to a laptop computer, and
- calculating and graphing the annual population estimate for each species.

The narrative will need to include a list of the SOPs, perhaps in the form of a flowchart, so users can quickly see which SOP is required to complete a given task.

The procedures will require a different format from the narrative portion of the protocol. Procedures are instructions, and they must be geared specifically to the intended user. The narrative should explain assumptions about who will use each procedure. These assumptions will be important to ensure that the procedures are written at a level of detail appropriate for the intended users. The relationship between the level of detail to be provided in the procedure and any training program is important, and should also be explained in the narrative.

Wieringa et al. (1998) provide an excellent overview of procedure writing. They make the point that the person who will use the instructions has divided attention: they are trying to perform a task while following the written guidance. Thus, it becomes critical for formatting to improve readability under the worst conditions of expected use. The instructions need to be written as steps with appropriate usage of placeholders, emphasis, and organization. A benefit of writing procedures in the form of steps is it becomes clearer where possible missteps might occur, and where quality control checks should be established. Numbering of steps helps, and will provide a convenient way to track revisions to the methods.

The format of the various procedures to be used in monitoring will vary depending on the type of work to be performed. If the procedures will be used in the field in a variety of weather conditions, a conveniently sized handbook format with waterproof pages might be appropriate. For procedures used in the laboratory, a more standard report format could be used. The important point would be to test out the actual conditions of use and make sure that the format helps the intended user actually operate in a manner that produces consistent and comparable data.

Relationship of Protocols to Other Aspects of the LTEM Program

Protocols have a pivotal role in the operation of the LTEM program. Protocols have links to almost every aspect of the monitoring process. Protocols have specific relationships to the (1) development process, (2) training and quality control, and (3) data management. All of these linkages lead ultimately to the production of trustworthy data that can be used for their intended purpose. It is worthwhile to point out and elucidate some of these linkages because they affect how protocols should be written.

Links to the Development Process

The entire monitoring program development process (see Figure 4) focuses on producing protocols that, when carried out properly, will allow the data to be collected, analyzed and reported in a way that meets the program's goal. Protocols represent the end product of what may have been a lengthy and convoluted development and testing process. It is important to capture this protocol development history within the protocol itself. The appropriate place for this is in the narrative.

This protocol development history is critical in the peer review process that needs to occur before protocols are officially sanctioned. For peer reviewers to determine whether the draft protocol will meet the objectives, they will need to see the results of pilot studies, any sensitivity modeling that occurred, and other background materials that were used in the protocol development process. Thus, while the SOPs, as instructions, would not include data, the narrative portion of the protocol needs to include, or refer to, data that were collected and analyzed in the process of developing the protocol. These data need to be available for peer reviewers looking at the adequacy of the protocol for meeting the stated objectives.

The protocol development history should also include information about methods that were considered or tested but later rejected. The reasons such methods were rejected are important to understanding what methods eventually are adopted. It is possible that a promising technique was overlooked or rejected based on faulty reasoning. Peer reviewers and future LTEM managers and Park Leads will need to evaluate these contingencies. In addition, problems that prevented use of a certain technique at one point in time may later be overcome, by technological developments or increased funding, leading to a change in methods. Such changes need to be carefully evaluated prior to adoption. Understanding the full history of the protocol's development will be critical to such evaluations.

Links to Training and Quality Control

There is a relationship among the level of detail provided in the SOPs, the skill level and experience of the people hired to carry out the SOPs, and the training that needs to occur as part of quality assurance/quality control. Protocols serve as the foundation for training of the personnel that will be making measurements. Each protocol should, in fact, include an SOP regarding training. The protocols also need to include clearly spelled out quality control checks.

Links to Data Management

In any long-term monitoring program, methods will change over the years. Reconstructing the exact methods used in any one year can be difficult or impossible. Yet, without knowing what methods were used in a given year, we diminish or lose the use of that data for comparisons. One of the great advantages of the database management system to be used in the Denali LTEM program is the ability to make a definitive link between the data collected via a protocol and the protocol itself. This requires that the exact version of the protocol or relevant SOP receive a code, which becomes a field in the database for the data collected in a given year or on a given date. The protocol and SOP codes can be linked to a digital copy of the actual protocol and SOP, also stored in the database. This system of documenting the methods used will greatly facilitate the ability of future users of the data trying to ascertain whether comparable methods were used. This system of documenting protocol changes and which protocols were used in any given year will need to be planned for and kept in mind as the protocols are being written, and as the database management system is developed.

A Higher Standard

A great deal of work will be involved to write the protocols to the level of detail required to support long-term monitoring. There may be resistance to the idea of using procedures and quality control checks throughout the data collection and analysis process. But, without the clear statements of methods and rationale for using them, without records of what methods were actually used, the quality of the data will not be known and the ability of the monitoring program to achieve its goal diminished. A substantial amount of work has gone into the development and testing of monitoring protocols to ensure that the methods used will be consistent and comparable over decades to centuries. To fully realize the investment in the monitoring program, the protocols must meet this higher standard.

Afterword – Looking Toward a Network Model

"Being genuinely curious and willing to learn from both success and failure will ultimately strengthen your program" (Margoluis and Salafsky 1998).

A glance into the future indicates that while long-term ecological monitoring is not new, there is still considerable attention on what, how, and when to monitor. Furthermore, funds for monitoring will likely never be sufficient to provide all the answers. In 2001, the NPS is gearing up for some significant changes in their original LTEM prototype model to address some of these concerns. Recently the NPS has moved toward a network-based "vital signs monitoring program" and has divided all the parks with significant natural resources into 32 networks. Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve encompass the Central Alaska Network. The intent is to eventually link the prototype LTEM model into the network monitoring model. The first phase will initiate a gradual transition (fiscal year 2001 through 2002) from an intensive individual park focus to a more extensive network focus. The greatest opportunity within the Central Alaska Network is to encourage synergy through direct staff links, direct data links, quality assurance, and quality control systems.

As previously discussed, the Denali LTEM program was selected in 1992 as a prototype park to develop and test methods for monitoring in subarctic parks. The prototype parks provide a package of common monitoring tools that can contribute to the NPS monitoring effort. Although Yukon-Charley and Wrangell-St. Elias were not directly involved in the prototype model, they also have moved forward with several outstanding monitoring efforts. For example, Yukon-Charley developed an ecological map based on the principles outlined by Bailey (1996). The primary objective was to delineate regions that have a consistent geographic pattern of ecological condition. The National Inventory and Monitoring Program funded this study through the Yukon-Charley Rivers National Preserve bird inventory project. In 1999, Wrangell-St. Elias initiated a monitoring program to address the effects of spruce bark beetles on the forest composition in the Copper River Basin (Allen and Wesser 1999). Both parks recognized that any monitoring actions recommended or implemented should contribute to the larger effort that supports a comprehensive long-term ecological monitoring program in the future.

We recommend that the time is now to begin "thinking like a network" and building on the "lessons learned" and using the "stuff in our toolbox" that the Central Alaska Network has acquired over the years. As a network, we realized from our experience that time is needed to gain an understanding on what, how, and when to monitor before we can fully implement a long-term ecological program. Furthermore, the transition from a single park approach to a more multi-park approach will not be easy and cannot be done overnight. It will require creativity and ownership in the design from all three parks.

Looking toward the future we realize that there are significant challenges to face. However, the network links between parks will:

- Foster a stronger cohesiveness and working relationship.
- Provide integration and increase cost effectiveness of the network program.
- Provide opportunity for sharing of staff and expertise.
- Provide integration across boundaries.
- Provide a common bridge of communication.
- Provide opportunity for comparative studies that improve our understanding, such that we make sound, informed decisions.
- Provide a coherent strategy for sampling design, modeling, and data interpretation.
- Advance us toward the overall goal of preserving park ecosystems.

Finally, long-term ecological monitoring is the only logical approach for detecting and documenting resource changes, and to understand the forces driving those changes. The major challenge for the future will be building the organizational structures and securing the necessary funding and staff to accomplish these objectives.

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Acknowledgments

Over the years, the Denali LTEM program has directly and indirectly involved a great many people, and we owe thanks to all of them. This Conceptual Design, coming as it does some nine years into the program, reflects what we have learned along the way.

We begin by acknowledging Boyd Evison, former director of Alaska Region of the National Park Service (NPS), whose vision of the role long-term ecological monitoring could play in preserving parks helped spur the NPS to enter the monitoring business. We also credit the late John Dalle-Molle, former Resource Manager at Denali, for his vision of how long-term monitoring could help Denali.

The Denali LTEM program would not exist without the support of national programs within the National Park Service and the U.S.Geological Survey, Biological Resources Division (BRD). For their support, through thick and thin, we thank Gary Williams, Director of the NPS Inventory and Monitoring (I&M) Program, and Norita Chaney, Status and Trends Program Manager for USGS-BRD. The recent addition of Steve Fancy, Monitoring Specialist, to the NPS I&M Program has been most welcome; his guidance and support during the past year have been especially helpful.

More locally, Steve Martin, Superintendent of Denali National Park and Preserve, has repeatedly expressed his strong support of long-term ecological monitoring, not only for Denali but for all Alaska parks. The support and guidance of Bill Seitz, Director, USGS-Alaska Biological Science Center, have also been crucial.

Over the past two and a half years, I (Karen) conversed with a great many people about monitoring and about Denali. I specifically thank: Layne Adams, Maggie Arend, Andrea Blakesley, Susan Boudreau, Lynne Caughlan, Sarah Conn, Ed Debevec, Roseann Densmore, George Dickison, Paul Geissler, Bill Halvorson, Dot Helm, Dana Hoag, Leslie Holland-Bartels, Gail Irvine, Kurt Jenkins, Penny Knuckles, Glenn Juday, Lyman McDonald, Trent McDonald, Carol McIntyre, Sandy Milner, Gordon Olson, David Peterson, Eric Rexstad, Carl Roland, Scott Rupp, Tom Smith, Page Spencer, Tony Starfield, Joe Van Horn, and Andrea Woodward. These conversations have greatly informed my thinking, and I am grateful for everyone’s time, patience, and interest.

I (Susan) am deeply indebted to the entire Division of Research and Resource Management, especially, the guidance and encouragement from Gordon Olson. Thanks also go to Karen Oakley. I am very much aware that the task to complete the Conceptual Design in a reasonable timeframe would have been impossible without her support and her dedication to the LTEM program.

We turned to several individuals for help in putting this document together. For their contributions to this document, we thank Jerry Belant, Lynne Caughlan, Mark Clark, Carol McIntyre, Carl Roland, Pam Sousanes, and Leslie Viereck.

We owe tremendous thanks to our editor, Jan Timmons, and our graphic designer, Sioux-z Humphrey. They not only agreed to work with us on very short notice, but their contributions were substantial. Jan kept us clear and consistent, and Sioux-z made the figures come alive. Perhaps the greatest benefit, however, was unexpected. In the processes of editing the document and creating the graphics, we had to explain our vision for the Denali LTEM program, thereby clarifying our own thinking.

Finally, we thank our reviewers: Steve Martin, Gordon Olson, Bill Seitz, Eric Knudsen, Eric Rexstad, Dot Helm, Sandy Milner, Carl Roland, Jamie Roush, Shan Burson, Andrea Blakesley and Carol McIntyre. Their insightful comments resulted in significant improvements to the design.

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Glossary

The following pages contain a list of terms defined specifically for the Denali LTEM program. While some of these concepts may have broader meanings and implications, the definitions in this Glossary are meant to facilitate use of this Conceptual Design.

abiotic - The non-living material components of the environment such as air, rocks, soil particles, inorganic compounds, coal, peat, and plant litter.

adaptive management monitoring - This type of monitoring is an integral, if not inseparable, part of a management program. A cause-effect relationship is known, and when the chosen indicator variable reaches some pre-determined threshold, a management action is taken.

aquatic systems - Interaction of biological and physical components in a water-based environment.

arctic haze - pollution that occurs throughout the circumpolar north, including Alaska, in the late winter and early spring, from industrial sources in eastern Europe and Asia.

attribute – any biotic or abiotic feature of the environment that can be measured.

biological diversity or biodiversity - The variety of life and it's processes, including the variety in genes, species, ecosystems, and the ecological processes that connect everything in ecosystems.

biotic - Pertaining to any aspect of living components.

ecological dynamics – the relationship and interactions of the physical, biological, and social components of an ecosystem.

ecosystem - Naturally occurring, self-maintained system of varied living and non-living interacting parts that are self-organized into biophysical and social components.

GIS (Geographic Information System) - A computer system that stores and manipulates spatial (mapped) data.

indicator – a measured attribute that infers the quality, health or integrity of the larger system to which it belongs.

inventory – an assessment of the status of a resource at a point in time.

long-term studies – represents the research side of monitoring with repeated measurements over time for a purpose. The purpose being to understand ecological phenomena that can only be studied over decades or centuries.

long-term ecological monitoring – typically involves monitoring of a wide variety of species or ecosystem attributes whose relevance to immediate management issues may not be clear or explicitly justified. The primary goal is to detect changes or trends, including changes or trends that are unexpected.

monitoring component – are the key building blocks (physical environment, aquatic systems, vegetation, and wildlife) that provide the foundation for achieving the LTEM objectives.

process variation – the variation observed in an ecological attribute due to environmental variation (as opposed to sampling variation).

protocol – is a study plan that includes a narrative description (what will be done and why) of the overall monitoring plan and any number of Standard Operation Procedures.

quality assurance – application of procedures for assuring the reliability and defensibility of decisions that are based on analytical data. The primary objective is to help ensure that planned activities occur as they are planned.

quality control – the application of specific procedures in sampling and analysis that ensures accuracy of results and are fully under an investigator's personal control. For example, instrument calibration or comparison to reference materials of known value.

standard operating procedures (SOP) – are a major part of protocol design giving written instructions for the current and future people actually doing the work (e.g., equipment needs, supplies, training, data entry).

stressors – intrinsic and extrinsic drivers of change.